ECOLOGICAL ASSESSMENT REPORT

AMATHIKHULU AQUACULTURE DEVELOPMENT ZONE

(ADZ)

DOKODWENI, ILEMBE DISTRICT, KZN

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ECOLOGICAL ASSESSENT.
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Front page image	Hummock dunes at Amathikhulu – evidence of dune transgression

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Glossary of Terms and Abbreviations

Associes	Groupings of species, particularly plants commonly found to occur together
DAFF	Department of Agriculture Forestry and Fisheries
Dissipative	A dissipative beach is a wide beach with a low profile associated with high energy surf zones
Dune heel	The leeward extreme of a dune
Dune toe	The seaward extreme of a dune
Eco-morphological	The physical and ecological result of plant and morphological drivers,
Hs	Significant wave height
Offshore bar	A sand bar that forms a short distance from the coast upon which waves break
Psammo-	Of dunes
Reflective	A reflective beach is a narrow beach with a steep profile associated with a low energy point
Rip cell	A seaward current carrying water away from the coast
Sand sharing system	The area between the outer bar and heel of primary dune
Scandent	climbing
Senescence	Die back or death
Slack	A valley or depression with the dune cordon
Supra-tidal	areas above the high water mark
T	wave period

Executive Summary

The Amathikhulu Aquaculture Development Zone is an initiative of the Department of Agriculture, Forestry and Fisheries to promote and develop South Africa's aquaculture industry. The Department has identified a site at Amathikhulu, just north of the estuary of the Amathikhulu River as a potential site for the development of a zone that undertakes various aquaculture projects.

The identified site presently, and to a greater extent in the past, engages in a number of aquaculture initiatives, primarily in the freshwater aquaculture industry. The ADZ will however expand to incorporate a mariculture component. To date a draft layout of the ADZ has been compiled. This spatial plan has been used to evaluate the impact of the ADZ on the surrounding natural environment, through an ecological evaluation that was undertaken between July 2017 and January 2018.

The findings of the ecological evaluation indicating that much of the area of the proposed ADZ has been subject to a number of anthropogenic interventions, initially to stabilise transgressive and prograding dune field that lie within the coastal frontage as well as the establishment of the Amathikhulu Fish farm in the 1980s. The proposed plan for the ADZ takes advantage of the existing infrastructure found within the site.

Howsoever, two factors have come to the fore in respect of the site, namely; an evident transformation in the immediate and regional coastal environment, where coastal erosion and dune transgression have become rapid and significant and bio physical changes and seral advancement within some portions of the abandoned lands have given rise to relatively diverse, "semi-natural" but eco-morphologically functional environments.

Using data obtained from site reconnaissance, historical imagery, as well as other forms of evaluation, a development footprint for the proposed ADZ has been identified that accommodates the various bio-physical factors and processes in and around the ADZ site, while also forestalling any damage to infrastructure that may arise from coastal recession.

This development footprint presents a spatial representation of the extent of the ADZ that may be utilised without undue ecological impacts arising. However, given the fact that the nature of activities within the ADZ are generally unknown, both in terms of the technology that is to be employed and the nature of the products arising therefrom, impacts and ecological risks associated with each aquaculture activity within the ADZ should be subject to specific review prior to implementation. A number of key management interventions are also proposed that reduce the risk the the operations of the facility may have on the ambient environs at Amathikhulu. Subject to the above, the identified footprint set out below is recommended for sanction by the relevant authorities.

INTRODUCTION

Nuleaf Environmental Consultants are the appointed environmental assessment practitioners presently conducting the environmental impact assessment process associated with the development of an aquaculture project on a portion of the property described as Amathikhulu Reserve (Figure 1). The applicant is the Department of Agriculture, Forestry and Fisheries, the Governmental department mandated to oversee and promote, *inter alia*, the sustainable use and development of fishery resources. A description of the proposed activity is provided below, however the primary objective of the development is to establish an aquaculture based production facility, known as an Aquaculture Development Zone (ADZ), that is both economically and socially driven. The Amathikhulu region is a highly populated, but economically disadvantaged area within the Ilembe District and as such expansion and development of the existing aquaculture facilities will lead to improvements in local employment opportunities, skills transfer and improved social conditions. The project would also serve local, regional and national interests.

SDP Ecological and Environmental Services has been appointed by Nuleaf Environmental Consultants to undertake an ecological evaluation of the land presently demarcated as having potential for utilisation as an aquaculture facility. The extent of this area is depicted in Figure 2 and includes portions of the coastline and estuarine environment as well as the terrestrial environment. Included in the study area is the existing Amathikhulu Aquaculture Farm. These habitats are inherently inter connected and, given the recent natural history of the region, should be given consideration from a holistic perspective as well as at a finer level of detail. As such, this report is compiled, giving due regard to the prevailing ecological drivers, these being;

- The near shore marine environment
- The supra tidal coastal environment, including the Recent dune slack and dune ridges
- Terrestrial habitat.
- The present wetland habitat.
- Faunal components identified or likely to reside within the subject area.

Given the above, this evaluation considers areas of ecological significance within the study area, highlighting these as areas of ecological "sensitivity" and this report presents recommendations on future land use practices.

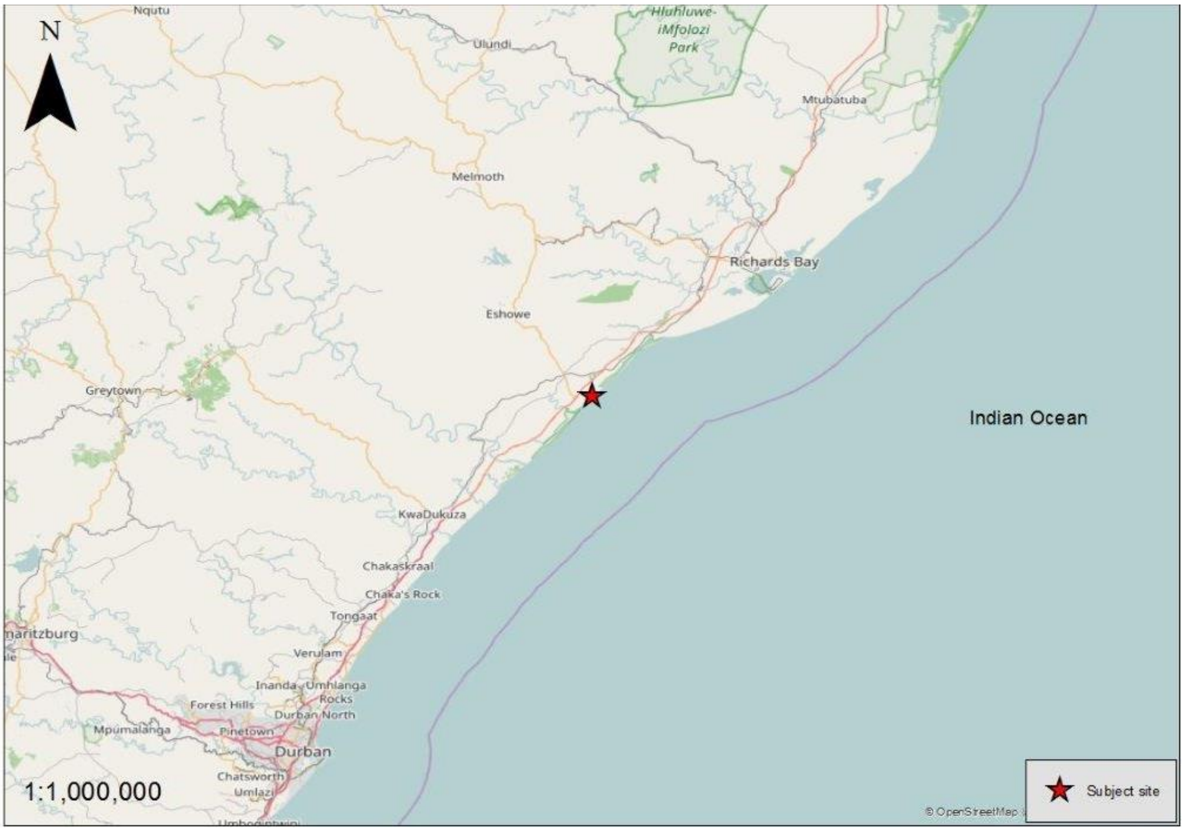

Figure 1: Map indicating subject site in regional context.

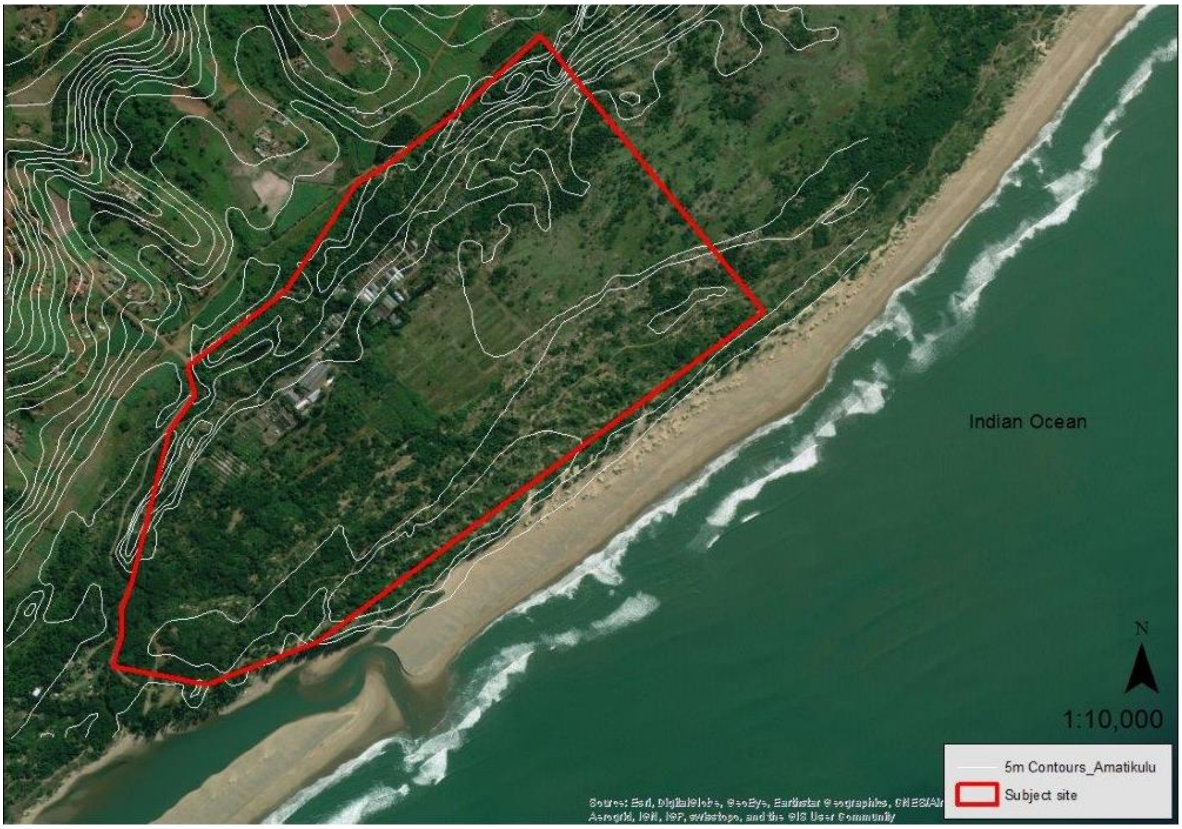

Figure 2. Map indicating outer extent of subject site. Note Amathikhulu estuary to the south of the site.

2. PROJECT DESCRIPTION

An Aquaculture Development Zone is a portion of land and/or sea that has been set aside for the undertaking of commercial aquaculture activities. The concept of an ADZ is to give assurance to potential investors and provide an enabling environment to them, that improves and encourages investor confidence in what is a technically challenging and complex economic sector. An ADZ aims to offer a number of aquaculture services, such as physical infrastructure, operational and management support to investors, while managing the various risks that are broadly associated with aquaculture. ADZs have been identified within the national Aquaculture Policy and Operation Phakhisa, which has the objective of creating an enabling environment that promotes the growth of this sector within the South Africa economy.

Amathikhulu was identified as a potential site for the establishment of an ADZ, following a preliminary national evaluation of possible sites across the country. Presently, the proposed ADZ site is subject to a number of evaluations which include economic and engineering aspects for the proposed development. This has given rise to a preliminary site development plan which is presented below in Figure 3. Aquaculture is a broad term and the exact nature of the activities to be undertaken are generally unknown and may change over time along with changes in technologies and market demand for differing products. Initial consideration is being given to the production of dusky kob (*Argyromus japonicas*) and barramundi (*Lates calcarifer*), as well as a number of marine shell fish species and invertebrates. Freshwater species that are also subject to consideration include tilapia (*Oreochromis spp*), sharp tooth catfish (*Clarias gariepinus*) and the Nile Crocodile (*Crocodylus niloticus*).

The proposed ADZ lies at 29°04'26"S/ 31°38'49"E. The preliminary site development plan indicates an overall land requirement of just under 109 ha. The site is presently utilized for the commercial production of ornamental fish, water plants and pet food products and has been utilized in the past for the commercial production of prawns. Such activities have been undertaken on a far more expansive basis in the past with the commercial facility historically covering an area of approximately 40ha, although presently, only about 15ha is utilized by the operation. The infrastructure within the subject site comprises of gravel roads, a range of buildings including offices and warehouses and numerous ponds and related impoundments required for the production of fish and plants. A water treatment facility is also present on site.

Figure 3. Preliminary plan of ADZ (source AquaEco)

The ADZ initiative will see the following activities being undertaken in Phase 1:

- the refurbishment of earthen ponds and tunnel based tank systems that were historically used for prawn and ornamental fish culture
- the installation of water supply and upgrade of treatment facility for farming activities.
- the development of a grow out facility for fingerlings.
- the construction of a feed store and other storage facilities.
- fish processing facility.
- the construction of offices and administration buildings
- a seawater intake and discharge pipeline with pump stations and a holding reservoir

The facility will be fenced and secured. Access to the road may have to be upgraded.

3. METHOD AND APPROACH

It follows from the above, that the ADZ and its associated infrastructure will, to a large extent, incorporate areas that have already been subject to transformation under the previous and present land use regimen, however given the position of the site and the bio-physical nature of the affected landscape, specific consideration should be given to;

- The impacts that such upgrades may have on the prevailing landforms and habitat. Ecologically important habitats that are considered to lie within the broader study area and may be affected by the development, include the beach-dune habitat form, portions of historical estuarine- wetland environment and emergent swamp forest identified at points around the site.

- The present level of environmental services provided by the above habitats require evaluation in order to forecast possible impacts on their ecological state which should inform decision makers, engineers and other members of the professional team on the final layout and operational aspects of the ADZ.

- It follows that the situation of the ADZ within a dynamic zone such as the supra tidal coastal environment may in turn pose a threat to infrastructure and operations of the facilities and in this regard sound planning would ensure that such risks are recognized and addressed.

The recent historical imagery of the Amathikhulu River mouth and the immediate dune cordon to the north indicate that the prevailing habitat within the study area has been significantly influenced by human activities. In evaluating the coastal environment, a high-level review was undertaken of all pertinent information relating to the regional marine and meteorological factors that affect the coastline around Amathikhulu, including the wind and wave regimen. Data was obtained from various sources, in particular www.meteoblue.com ; www.noaa.gov/research, www.swell.com, www.eumetsat.int and www.csir.com . This data provides information relating to surf conditions prevalent along the Kwa Zulu Natal and Ilembe coastlines and informed on the eco-morphological drivers of the region and recreational opportunities along the coastline.

Site reconnaissance was undertaken between October 2017 and December 2018, where consideration was given to *inter alia*, the inshore, sub tidal and inter tidal environment and the beach and dune environments, as well as more terrestrial and aquatic/wetland habitats. Data was collected from a number of sample sites and collated to allow for the identification of habitat forms and further interrogation of data leading to a spatial rendition of the site's various habitats. Figure 4 below indicates the various sample points.

Figure 4. Aerial image indicating sample points at Amathikhulu.

The delineation of wetlands was undertaken utilizing accepted determination techniques contained within "A Practical Field Procedure for Identification of Wetlands and Riparian Areas" (2005). Reference was also made to the updated manual (DWAF 2008). A description of the rationale is provided below.

Identification using vegetation indicators

Following review of aerial and topographical information, the identification of obligate and facultative wetland plant species in and around potential wetland environments was undertaken. Due to the continuous or regular saturation experienced within wetland environments, soil chemistry differs from mesic or dry environments, giving rise to specific plant associations or groupings (hydrophytes) within wetland environments.

The dependence of hydrophytes on wetland conditions varies from species to species. As a result, these species can be classified according to their occurrence within wetland areas. Four groups of wetland associated plants have been classified and are as follows (as set out in DWAF 2005):

1) Obligate wetland species
2) Facultative wetland species
3) Facultative species, and
4) Facultative dry-land species

A dominance of the first two groups, indicate wetland conditions. In addition, the species present can be used to determine the three wetland zones, permanent, seasonal and temporary, however the difference between seasonal and temporary wetland areas is often ambiguous, resulting in the two categories being combined occasionally.

Identification using soil indicators

Soil characteristics were also utilized in the delineation process. Under fluctuating periods of water inundation, as well as the permanent presence of water within the upper soil horizons, minerals in the soil are either leeched from the horizon or are subject to chemical reactions, leading to changes in soil colouration and the presence of "mottling". The frequency of mottling indicates the degree of saturation and hence the wetland zone. In coastal environments soil indicators may not always be present.

Description of sampling methodology

During the site visit, a total of 6 sample points were taken and recorded using a Garmin GPS VI Montana. At the majority of the data points vegetation and soil form were recorded. The dominant vegetation within a 2 m radius of the inspection pit was identified and recorded.

Identified wetlands were classified to the level 4A classification (Ollis et al 2013). The classification details are provided below .

Using the above, a spatial rendition of ecologically significant environments within the subject area was compiled. Through application of a rational understanding of the various bio-physical dynamics associated with these environments, the ecological impacts of development within these areas can be predicted, as well as the risk that developments of this nature within these areas may pose to infrastructure and operations of the ADZ.

4. A REGIONAL PERSPECTIVE OF THE AMATHIKHULU ADZ

The proposed ADZ lies within two major eco-morphological features at Amathikhulu, namely the sand sharing system comprising of the nearshore zone, the beach and dune environment, as well as a portion of the paleo-estuarine environment of the Amathikhulu River and the older paleo – dune environment which lies to the lee of the sand sharing system. These habitats are driven by or affected by the nature of the offshore marine environment. Some consideration of these eco-morphological features is provided below. As such, the status and function of these features will determine the nature and level of ecological impact that will arise with the development of the ADZ.

4.1 The marine environment

The proposed site of the ADZ lies within a coastal zone that has been generally referred to (until recently) as being a prograding coastline (Green et al 2013; Cooper 1991 ; Tinley 1982). A prograding coastline, which can generally be considered an anomaly within the South African coastal context, is a shoreline that shows extensive accretion in a seaward direction. This progradation is driven by a high input of sediment from a (normally) proximal source, which in the case of Amathikhulu is the nearby Tugela River and in part, the Amathikhulu River (Green 2013). As such, the longshore drift, which is generally in a northerly direction, drives sediment from in and around the mouth of the Tugela River towards the Amathikhulu coast and beyond (Cooper 1991).

Notably, recent events have seen a regression of the coastline, most recently during the period 2016 to date. In 2016 significant erosion was recorded immediately to the north of the Tugela River mouth which has seen the shoreline retreat by 94m in approximately 6 years – a rate of 15m per year. Figure 5 below indicates this severe level of regression.

Figure 5. Image of Tugela Mouth showing recent recession. 2013 on left and 2017 on right.

The cause of such retreat is generally unknown but it is considered to be part of the long term drain of sands from coastlines on a global scale (Bird 2000), that is marked by a reduction in the sediment reserve that has been available in the coastal environment since the mid-Holocene (Thom, 1984). Smith *et al* (2010) have however, suggested that the periodic erosion and accretion of coastlines may be cyclic in nature, following meteorological and hence maritime, trends driven in association within the lunar nodal cycle (LNC).

It follows that some consideration of the wave and wind regime in the region is required as this is the primary driver of the supra tidal coastal environment and in part, the site of the ADZ.

4.2 The near shore environment

The Amathikhulu coastline receives two significant swell types, namely a wind swell, driven primarily by the predominant north easterly winds and derived from that point; while longer period groundswell is evident from both an easterly and southerly direction (Figure 6). The swell direction, as well as the wave height and period are important physical factors that determine the nearshore coastal environment, controlling the nature of the shoreline and the morphology of the beach, the back-beach and in part, the dune cordon. As can be noted from Figure 6, the dominant swell frequency along the Amathikhulu coast is a function of both the north easterly and south easterly wind regimen and also accounts for the origin of the dominant swell period, which is on average 8s and the dominant, significant wave height (Hs), which also originates from the east at an average Hs = 1.7m. The above data indicates annual trends and it is evident that seasonal variations arise, these being particularly evident during the mid-winter and late summer periods, where swell size and direction are determined primarily by the presence of the Indian Ocean high pressure (particularly in summer). The arrival of low pressure systems and cold fronts from the south is often more prevalent or intense, during the winter period and under these conditions, rapid erosion can arise along the shoreline.

The average wave period of 8s recorded along the KwaDukuza coast, indicates a wave of moderate power, however waves with periods of up to 18s are associated with the larger swells arriving along the coastline (Smith *et al* 2010), while wave heights in excess of 8m are annual events (Theron, 2010) (Figure 8). Other meteorological factors are also known to affect the Amathikhulu coastline ; these include cyclones and cut-off low pressure systems. Cyclones on occasion, stray far to the south of their normal latitude of 26˚ S or close enough to the Kwa Zulu Natal coastline for the accompanying strong winds and high seas to affect the shoreline of KwaDukuza. Such situations are uncommon, with the last such event of this nature being Cyclone Irene in 2011. Hewittson (2011), has indicated that cyclones are not likely to be the cause of major erosion events along the South African coastline. However, it is evident that *cut off lows* that remain stationary to the south east of the KwaZulu Natal coastline are responsible for the genesis of high wave conditions, as well as infra-gravity waves

(Davidson- Arnott , 2009; Butt 2012) which give rise to significant erosion events along the coast, particularly when they correlate with higher than normal tidal events (Smith *et al* 2011).

The data presented, indicates that the Amathikhulu coastline is subject to significant variations in the near shore marine environment, with some periods of extremely high wave conditions, while periods of almost "dead calm" also arise from time to time. However, the prevailing sea and swell conditions are generally "moderate" with a consistent wave action being the norm within the region.

The wave regime, coupled with other meteorological, geomorphological and biological factors serves to establish and drive the sand sharing system along any given coastline. Martinez (2004) defines the sand sharing system as the outcome of a process – response model which extends from the offshore bar, in close proximity to the break point of larger waves and the landward extent of sediment movement, which is driven by wave, current and wind along the coast. The terrestrial biotic and freshwater geohydrological influences on the sand sharing system may also be considered secondary drivers and serve to maintain or increase dune mobility and stability within the dune component of the sand sharing system (Figure 8). Notably, changes in either or both the marine and terrestrial drivers results in changes within the sand sharing system, making this environment a complex and dynamic ecological system.

4.3 The Amathikhulu Sand Sharing system

Both the drivers and various components of the coastal sand sharing system are, as stated, very dynamic, changing over varying temporal periods ranging from hours to decades and moving within an envelope that includes the supra-tidal, inter-tidal and sub-tidal zones. As a primarily sandy coastline, the identification and delineation of the sand sharing system along any portion of the KwaZulu Natal coastline is the first step to the management of the coast. Defining and delineation of the sand sharing system at Amathikhulu is considered below.

As indicated above, the Amathikhulu coastline has been generally considered to be a prograding system. Table 1 below, indicates qualitatively, the primary sources and sinks associated with coastal sediments in the Amathikhulu region (Davidson Arnott, 2010). From Table 1 it is clear that sediment supplied to the coastline is predominantly sourced from the Thukela River, with a smaller amount contributed by the Amatikhulu River itself (Cooper, 1991). Such supply is episodic (Cooper 1991) and until the more recent phase of erosion arose, this sediment accounted for the dune ridges evident along much of the Amathikhulu, Tugela and Siyaya shoreline. Sediment delivery is still significant in the immediate beach – dune interface immediately east of the proposed ADZ with the evident embryonic hummock dunes (Figure 8) being testimony to the ingress of sediment.

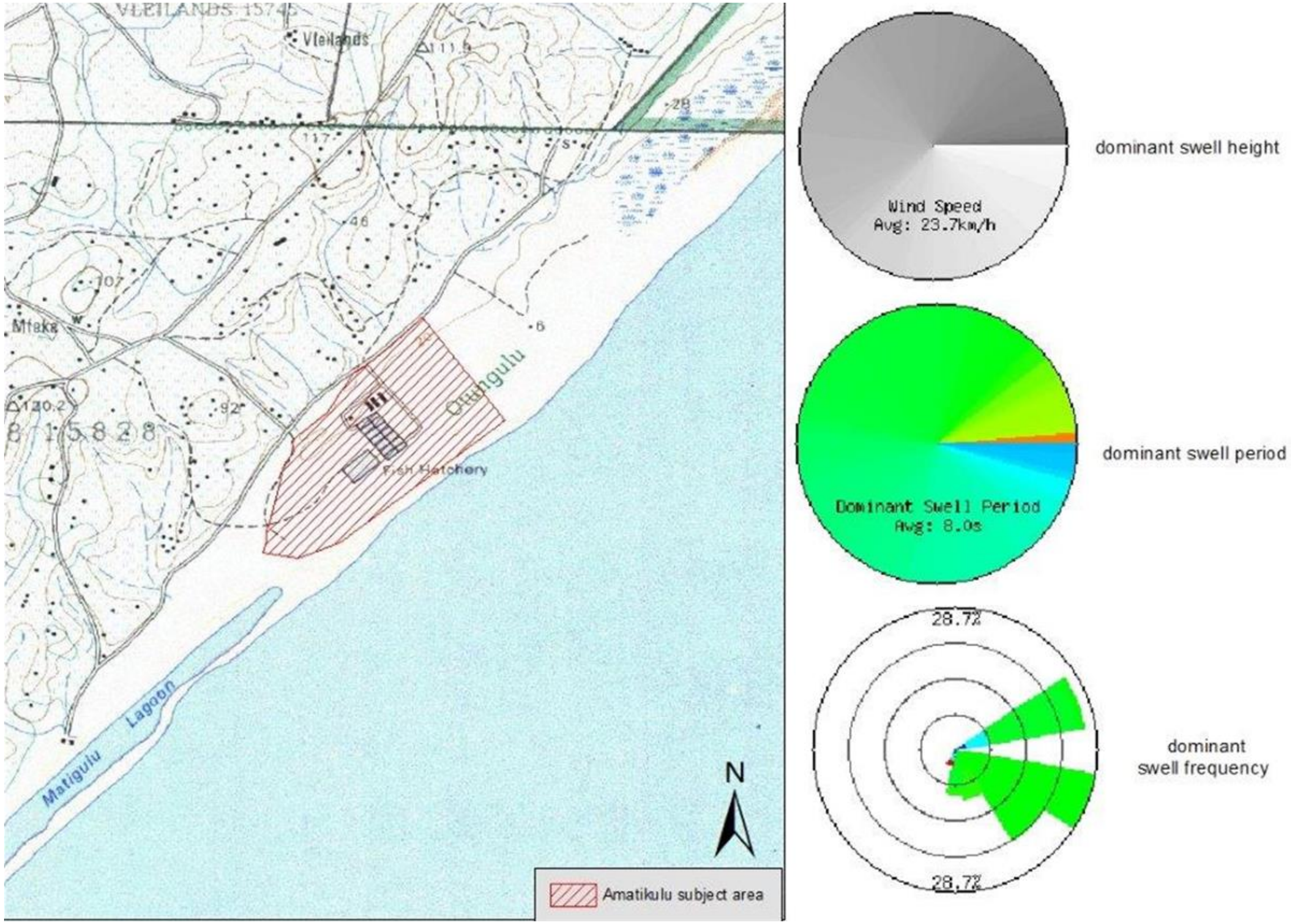

Figure 6. Map indicating Amathikhulu site with dominant winds and groundswells associated with the coastline

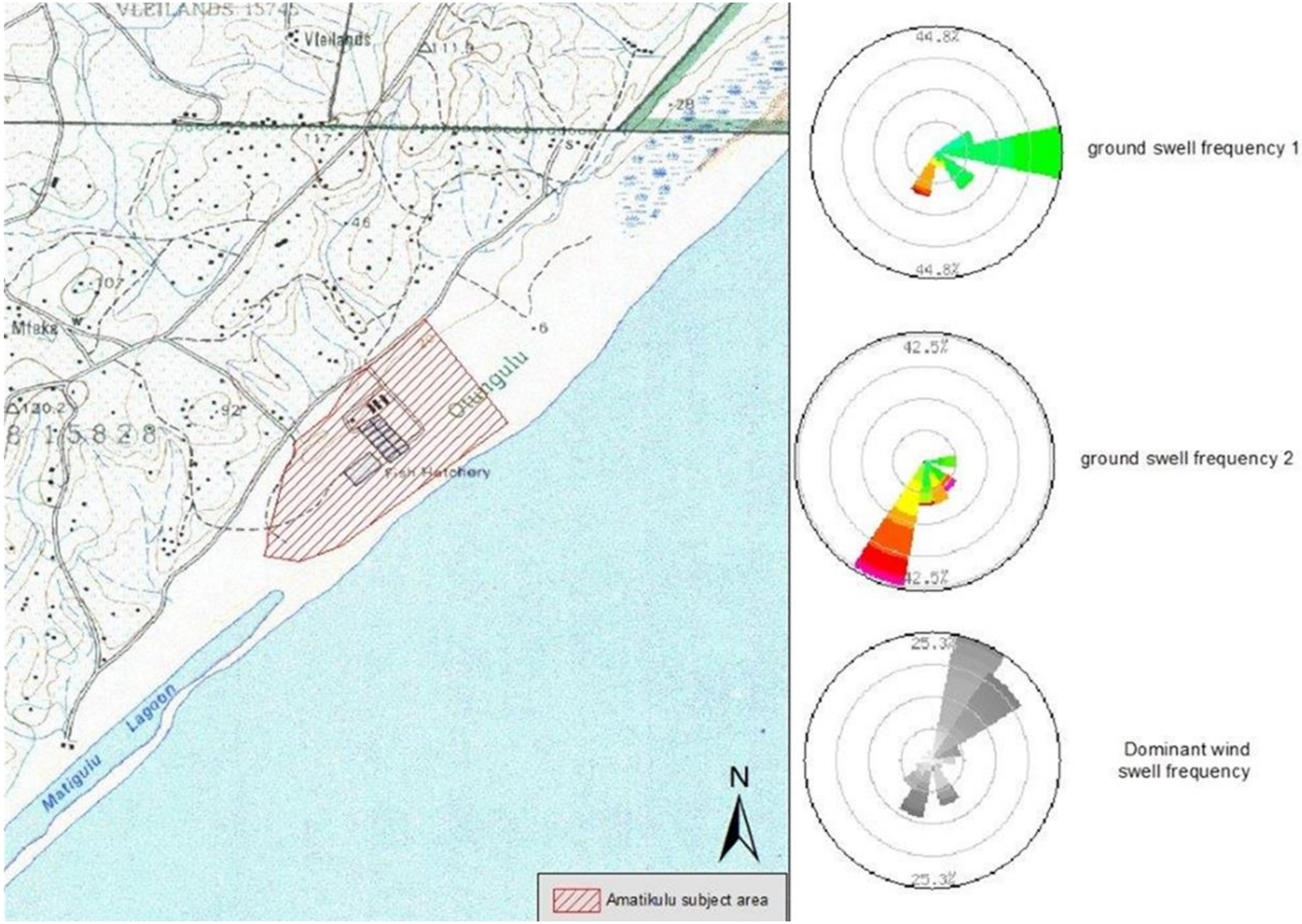

Figure 7. Map indicating dominant swell frequency, swell period and swell height

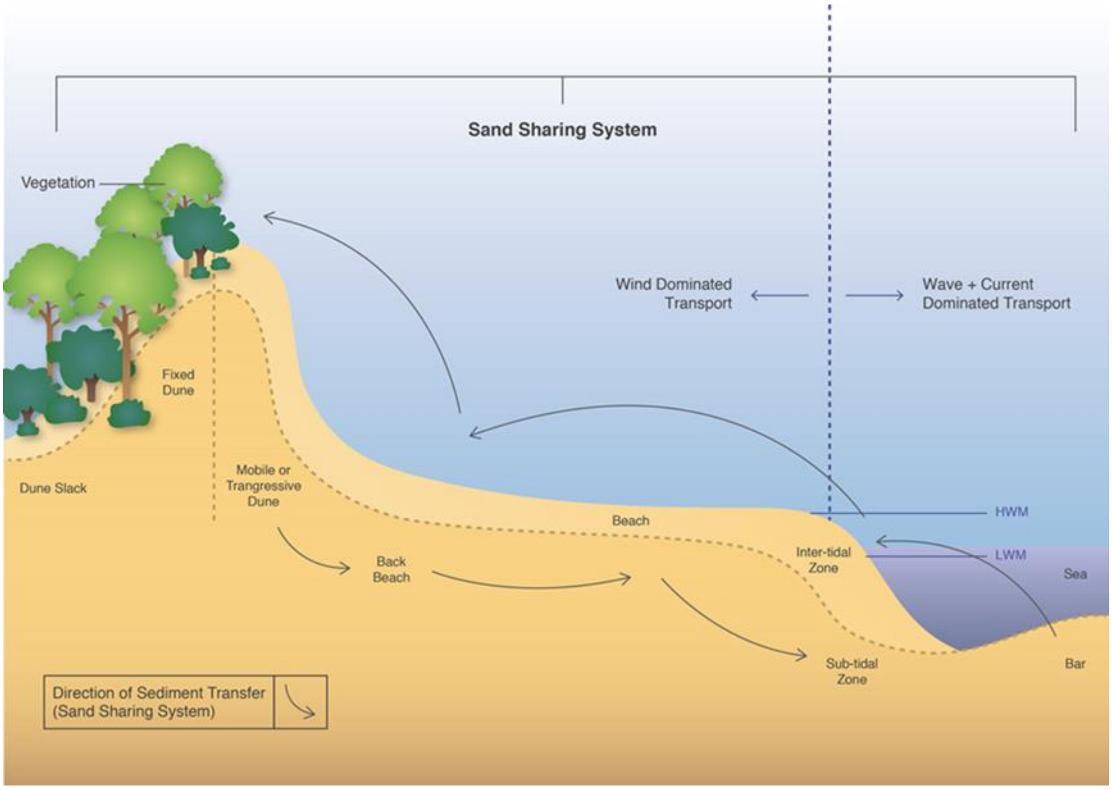

Figure 8. Illustration of the sand sharing system along a coastline and the exchange of sediment between the various components

Table 1. Qualitative evaluation of sediment sources and sinks at Amathikhulu

	terrestrial						marine	
description	volumes	source	Littoral transport in			source	volumes	description
			360000m3		620000 m3			
Tugela River	440000m3	Fluvial				Continental shelf	not identified	landward movement >-30m
Amathikhulu - Nyoni	? (< 24000m3)	Fluvial				Submarine canyons	not identified	loss of sediment over shelf
frontal and secondary dune cordon	1300tonnes/y	Coastal dunes				Precipitation and solution	not identified	considered minimal
inlets - blind streams	minimal	Fluvial						
Anthropogenic	not applicable	Beach nouruishment						
Anthropogenic	not identified	Dune stabilisation						
			360000m3		620000 m3			
			Littoral transport out					

Figure 9. Image of ephemeral hummock dunes and shoreline, located seaward of the ADZ.

From Table 1, it is however clear that sediment supply is generally fluvial, and at a broader level of consideration, terrestrial in origin. It follows that as the Tugela River provides as much as 70% of the sediment that is available along the shoreline at Amathikhulu and that the Tugela River is a critical component in the maintenance of a dynamic equilibrium within the sand sharing system at this point. Meteorological factors, long-term and short-term climate change, land use within the Tugela catchment and direct anthropogenic interventions within the river or its immediate environs are likely to alter the nature and volumes of sediment arising from the Tugela. Change resulting in a reduction in available sediment within the longshore drift will give rise to erosion of the coastline. As indicated in Table 1, other components of the system (the Amathikhulu River) play a minor role in sediment delivery although as indicated below, its influence both at a contemporary and historical level, on the region around the ADZ is of significance.

4.3.1 Modal beach form at Amathikhulu and the inshore beach environment

Wave energy is the dominant driver of the sand sharing system below the high water mark and high energy, long wave periods generally establish a dissipative beach (Short 1984) while low energy waves generally establish a reflective beach. Dissipative beaches are more conducive to dune construction and the onshore movement of sand for the building of dunes, although this too, is dependent upon the prevailing wind regimen. It follows that where the modal beach form is dissipative and the prevailing winds are onshore, subject to the nature of a few additional factors, such as grain size, increased dune transgression can be forecast. Further to this and as described above, where the outer bar is positioned distally from the shore, wave energy is dispersed further offshore leading to a more dissipative beach. Figure 10 below, indicates the position of the outer bar relative to 16 beach sample points that are positioned 100m apart.

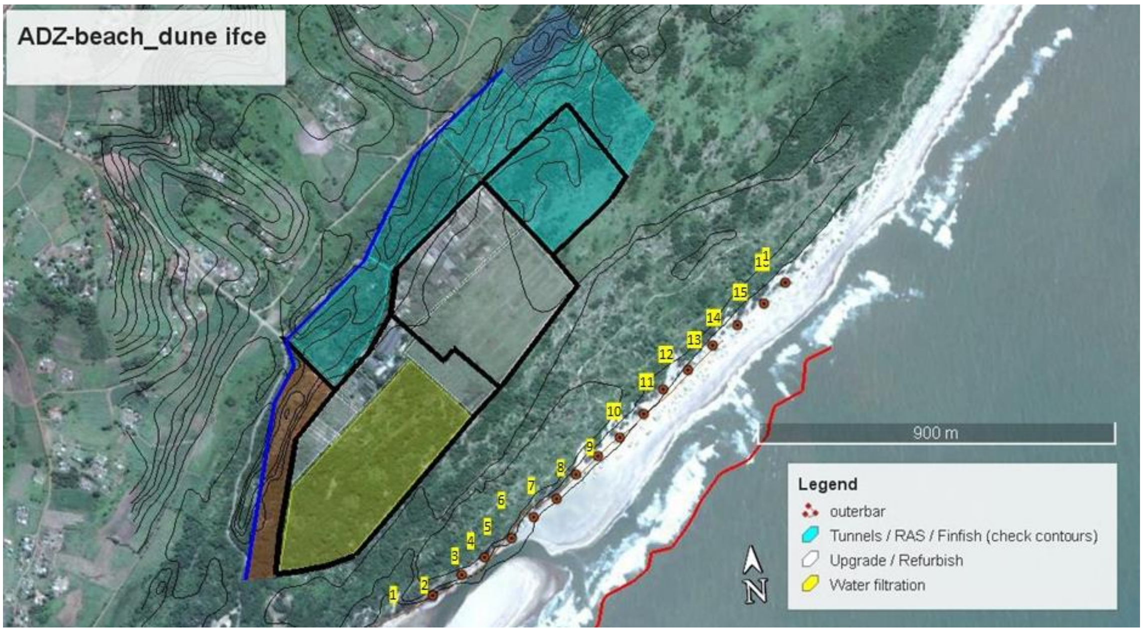

Figure 10. Sample points established along the frontal dune cordon at Amathikhulu

Using 2017, 2009 and 2002 aerial imagery an indication of the general placement of the offshore bar relative to the shoreline can be constructed. Figure 11 indicates the results of this analysis.

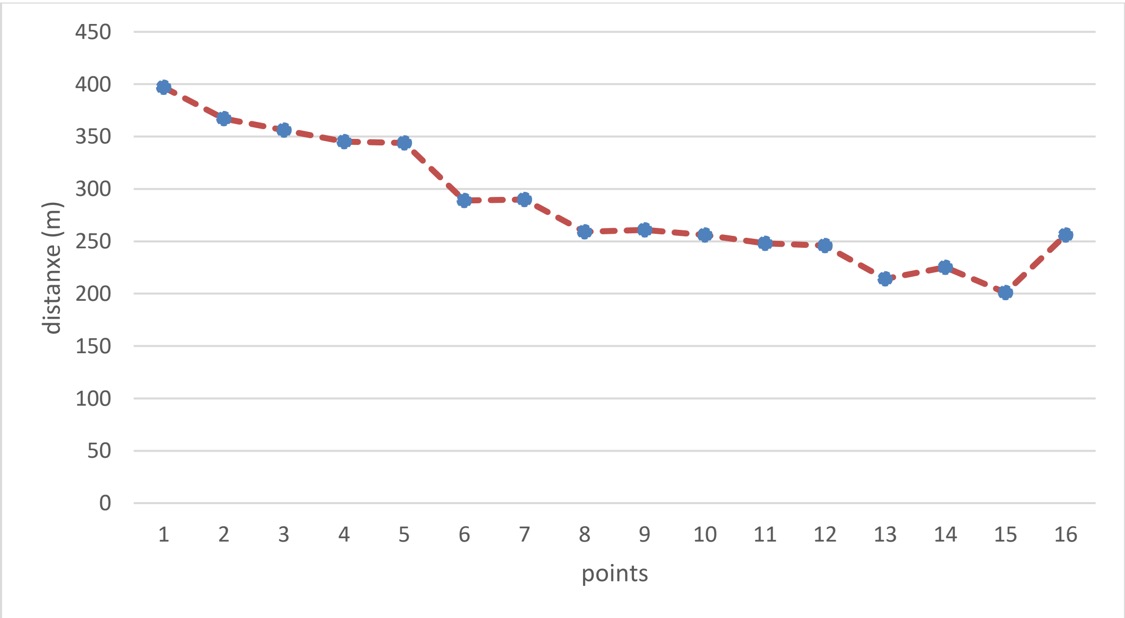

Figure 11. Graph indicating relative distance of outer bar from shoreline, from south (1) to north (16).

In general, the shoreline to the east of the proposed ADZ is modally dissipative, with a long, wide beach established through the formation of an offshore bar driven by a high level of available sediment. Comparatively, the outer bar at Amathikhulu lies at a distance of between 200 – 400m from the shoreline, while that of the coastline north of the uMdloti River (Tongaat), lies at a distance of between 20 and 60m from the shore. Figure 11 however, indicates that the bar lies considerably closer to the shoreline to the north of the subject site, indicating that incoming wave energy is dissipated considerably closer to the beach than at points further to the south. Consideration of a number of aerial images across subject site indicate the prevalence of ;

- A relatively deep inshore channel
- A number of *rip cells* to the north of the subject site

These features are depicted in Figure 12 and indicate that;

- Inshore, sub-tidal sediment transport north of the mouth of the Amathikhulu River is relatively rapid due to a deep inshore channel and a straight shoreline.
- A number of rip cells arise on a regular basis to the north. These features serve to disperse sediment offshore, while also creating a deeper bathymetry at these points, generally exacerbating erosion of the beach.

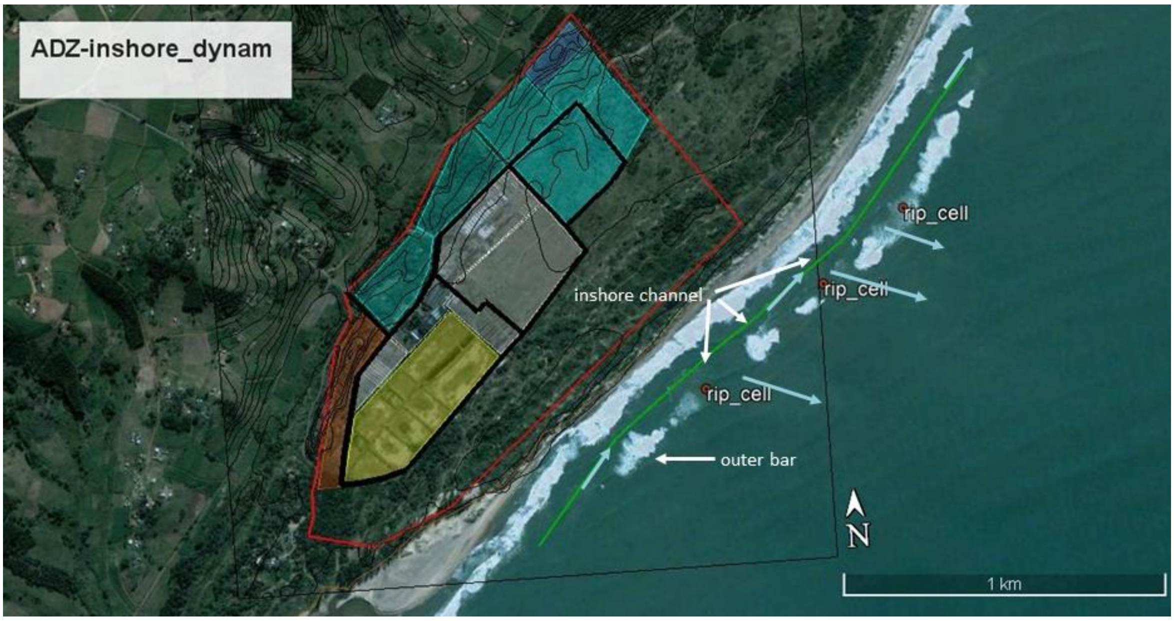

Figure 12. Aerial image depicting nearshore marine environment.

These features suggest that where a waning sediment deficit arises, erosion and beach and dune regression may arise. It also follows that where the ADZ requires that a marine pipeline is to be established, consideration should be given to both the significance of the inshore channel in terms of sediment transport and the presence of rip cells and their influence on beach morphodynamics and offshore sediment transport. Positioning of any pipeline to the north of the site, rather than the south is recommended.

4.3.2 The nature of the supra-tidal environment

The supra tidal environment at Amathikhulu has been subject to significant anthropogenic interventions over a timespan of approximately 80 years. The greatest single anthropogenic intervention in the subject area must be considered to be the planting of the exotic beefwood tree, *Casuarina equisetifolia*. This tree is native to the Australasian coastal environments of the south Pacific and is a most effective stabilizer of mobile sands (Pernas, 2013). The tree effectively accrues sand around its base at sapling stage, which leads to the formation of a small dune form around the tree. As the tree grows, sediment accumulates around the bole of the tree establishing a larger dune. Where a number of trees establish or are planted in a grove, these trees can form effective sediment sinks and lead to the development of large dune cordons. Such ecological strategy is effective in the low lying islands of the Pacific, and as such this characteristic has been exploited by Man in other regions, where sand stabilization and dune construct have been deemed desirable.

Figure 10 below indicates the subject site in 1953, prior to the establishment of a *Casuarina* plantation that extended across the Amathikhulu River, beach barrier, the western shore of the estuary and to the north, into the sand sharing system around the proposed ADZ. In particular, the progression of large parabolic dunes indicated that the area to the north of the estuary was particularly dynamic.

The planting of Casuarina was a direct intervention that sought to stabilize the mobile dunes around the Amathikhulu River. Consideration of the 1937 aerial imagery of the same area indicates, as it does in the 1957 imagery, that the sand sharing system extended well beyond the contemporary "stable dune" environment. Aeolian sands were prevalent across the northern reaches of the estuary, effectively forming a wide dune slack that extended as far north as the Siyaya River, some 15 kilometres away. Also evident in the 1937 imagery are the regular dune ridges arising just above the back beach, parabolic dunes to the north of the estuary mouth and numerous, partly stabilized, mobile dunes which appear to be a combination of longitudinal and barchan dune forms, indicating a high sediment availability in the area (Psuty 1988). These mobile dunes probably shifted over relatively short time-frames, often revealing points of moist to wet inter-dune slacks. Such wetland environments are fed by the coastal aquifer which forms an interface with the saline marine environment in and around the frontal dune cordon. (Figure 17).

Figure 13. Comparative imagery of the ADZ in1953 (left) and 2015 (right). The 1953 image shows distinct parabolic dune forms which were later stabilized and have remained so since the 1950s.

The 1937 imagery can be utilized to determine the extent of the sand sharing system. This can be determined at two levels, namely the more recent sand sharing system, which comprises primarily of the seaward frontal dunes to the interface of these dunes with the dune slack; and using the model of Psuty (1988) a more historic extent that prevailed during the late Holocene period (between 980 and 6000 years BP (Cooper 1995 ; Ramsay 1990), when higher sea levels prevailed along this portion of coastline (approximately 3.6 to 1.5m above present levels) (Figure 14). Smith (*pers. communications*) suggests that given the recent, rapid erosion evident at Tugela mouth (up to 90m between 2016 and 2017) and the historical evidence associated with earlier sea levels, it would be more prudent to accept the more landward delineation of the sand sharing system as the *de facto* delineation.

Figure 15 indicates these features and the sand sharing system using the 1953 imagery, while Figure 16 shows the site in 1983. The earliest imagery shows that the ADZ and surrounds differed little from is eco-morphological state in 1953. It can however, be inferred that in 1937, the region showed a high level of transgression and that the parabolic dune forms align with the resultant wind direction of the southwesterly and south-southwesterly winds. As dune construct is a product of sediment supply, fetch and wind speed (Davidson Arnott 2010; Freiberger *et al* 1979), the reason why a transgressive dunefield is the eco-morphological norm around the ADZ, becomes evident; this being that:

- Sediment supply remains significantly high in this region, being derived either directly from the Amathikhulu River or the significant longshore drift (see Table 1).

- Fetch; (the distance of dry, supra tidal sand) over which the resultant prevailing southerly winds blow is significant (up to 1000m). The significance of the fetch component is exacerbated with the closure of the mouth of the Amathikhulu and its southerly migration (Green 2013), which increases the availability of sediments for entrainment and transport northwards.

- Wind speeds from the south are generally strong, mostly at speeds in excess of 5.5ms-1 and amount to nearly 30% of the annual recorded wind direction. Significant sediment movement arises at wind speeds in excess of 5 - 6ms^{-1}

However, as indicated above, land use managers in the region sought to stabilize the dune field and undertook the planting of more than 100ha of transgressive dune. The effect of such plantings has been significant from an ecological perspective (Figure 16) stabilizing transgressive dune and transforming the ecology of the area. Using the Psuty model (1988) it is evident that the frontal dune cordon progressed from the 1950s onward, from a transgressive beach and dune, through to a stable beach state, with slowly growing foredune. Since the 1990s however, the coastline can be judged to be now reverting to a transgressive beach with stable dune and in some parts, back to a transgressive dune. (Figure 17). This state of increasing transgression has arisen primarily on account of maritime and fluvial sand deficits as discussed above, but may also have arisen on account of the aging of the Casuarina and general senescence of trees within the plantation - these trees have a lifespan of approximately 60 years (Pernas 2013), while recruitment of juveniles into the plantation may have been curtailed for unknown reasons. In addition, it is likely that changes in the freshwater lens that lies beneath the dune cordon may also affect the state of the dune. Such change may be brought about by catchment-wide influences or more proximal activities, including the infilling and establishment of the prawn farm within a wetland environment, as well as sea level rise (Figure 18). Specific consideration of land use change within the site and its effect upon the prevailing ecology is discussed below.

Figure 14. Aerial image of site in 1953, depicting a transgressive coastal environment.

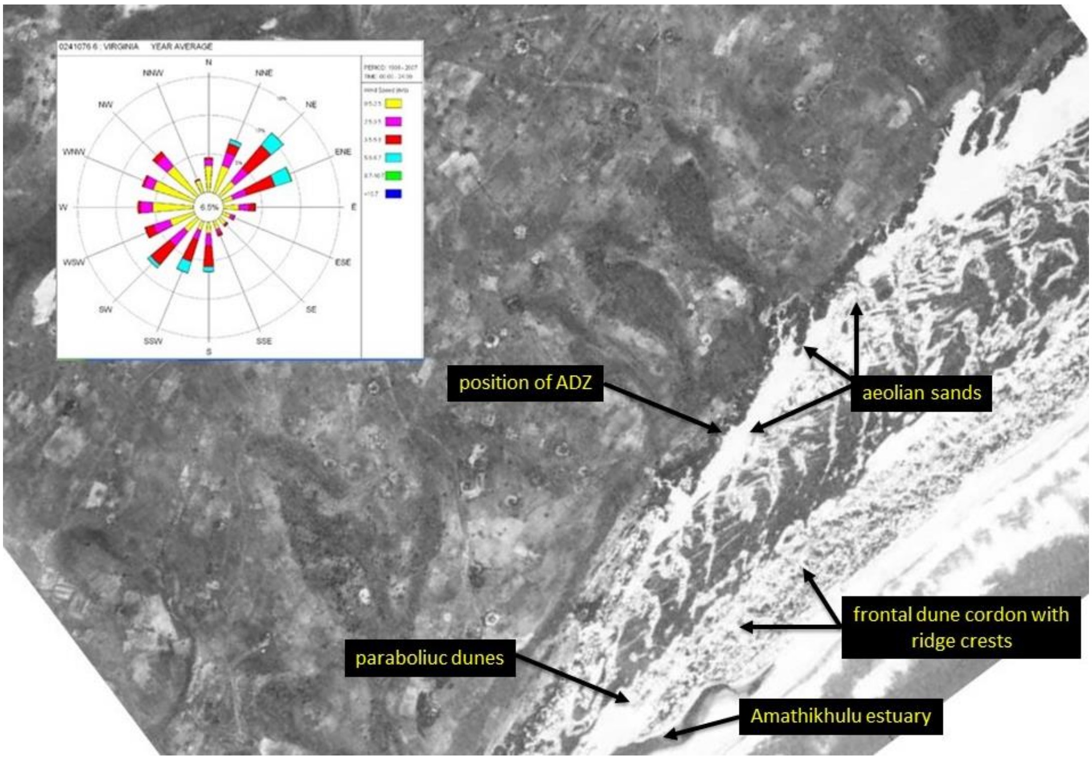

Figure 15. 1937 image of site indicating alignment of sand sharing system with prevailing winds and parabolic dune formation aligned with the south westerly winds.

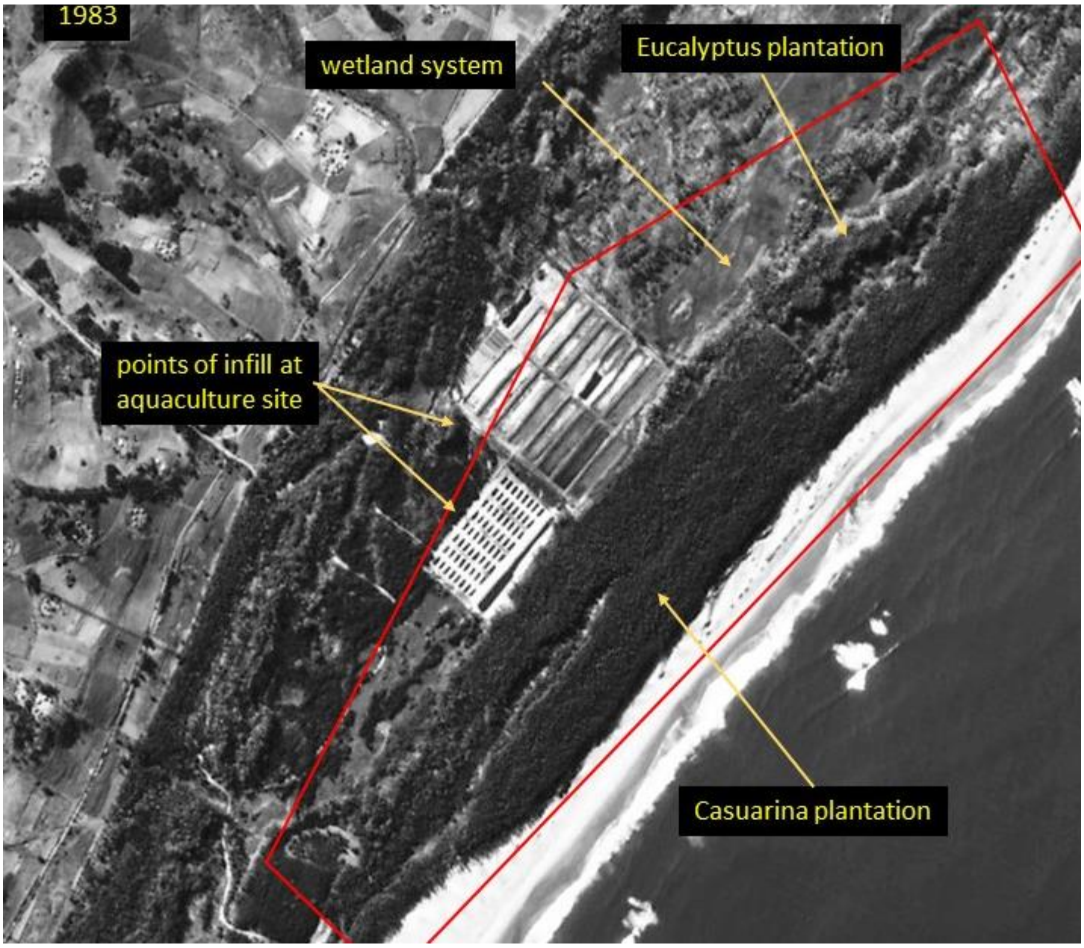

Figure 16. 1983 image indicating Casuarina plantation and extent of aquaculture project at that time.

Figure 17. Image of *Casuarina equisetifolia*, engulfed by sediments on Amathikhulu coastline.

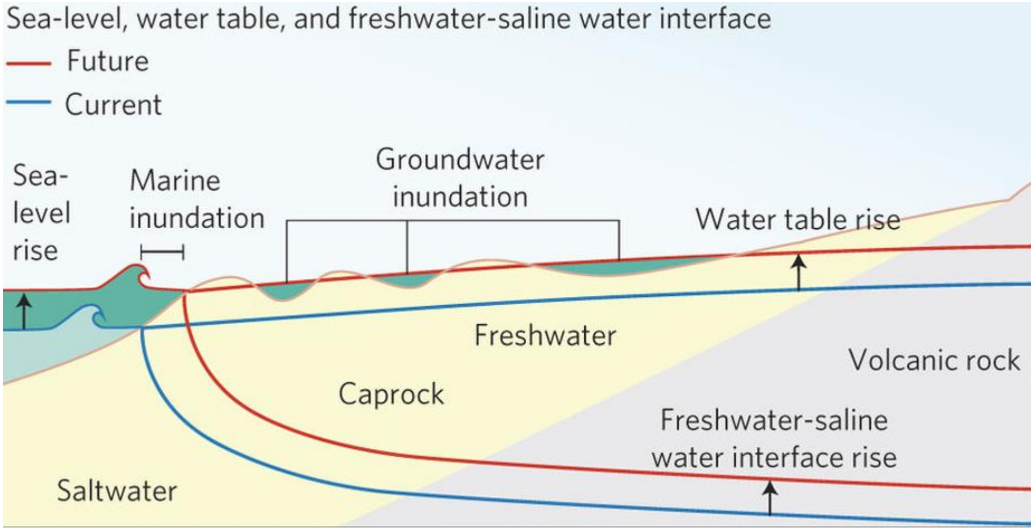

Figure 18. Stylised image of freshwater lens and beach (from Rotzoll K, 2012). Marine inundation may be responsible for the senescence of Casuarina on the frontal dune, but also raises the freshwater lens within the dune cordon.

4.3.3 Historical land use change since the establishment of the Amathikhulu Prawn Farm

With the defining of the sand sharing system around the proposed ADZ site, it is important to consider the recent historical context of the site and the influence that the construction of the Amathikhulu Fish Farm had on the prevailing eco-morphology of the area. Aerial imagery taken in the 1960s indicates that much of the landward transgressive dune had been planted to Casuarina and Eucalyptus in a bid to stabilize these areas. It is within these areas that the primary infrastructure of the fish farm was placed (Figure 19).

Figure 19. 1960 image showing stabilized areas in relation to the future fish farm (yellow circle)

It follows that prior to the construction of the fish farm in the 1980s, a large component of the site had been artificially stabilized, with direct influence on the ecology of the transgressive dune form and possibly, indirect influence on the adjacent wetland environment.

The establishment of the existing aquaculture project commenced in the early 1980s. The project entailed the establishment of a large number of tunnels which were placed upon cut, as well as infilled platforms within the former transgressive dune environments. Due to the underlying wet dune slack located to the east of the site, a large number of grow-out ponds were excavated. At depth, these ponds interfaced with the underlying water table and were most suitable for the retention of water. A network of small canals as well as reservoirs and remediation ponds were also established through the site, with the ultimate point of discharge being into an excavated pond located at the heel of the frontal dune cordon (Figure 20). Giving consideration to Figure 16 above, it is clear that the fish farm as established and operated in the 1980s and 1990s covered an area approximately 25ha in extent, however with the abandonment of much of the operations in the late 1990s and beyond, the operational area shrunk to approximately 10ha. This situation saw much of the lower elevated lands to the east reverting to a secondary hygrophilous habitat, or where areas were less inclined towards inundation by water an *Acacia kosiensis* dominated landscape arose.

Figure 20. Settling pond where discharge from aquaculture project collects and percolates into the dune cordon

4.4 Habitat form and structure

The recent history of the site accounts for much of the prevailing habitat forms encountered within the subject area. Figures 21 and 22 below, indicate in a stylized manner, how the eco-morphology of the land in question has been altered by various anthropogenic interventions. As explained above, the initial stabilization of the sand sharing system altered the evident transgressive nature of this system, thereafter, some 25 to 30 years later, significant earthworks ensued in the establishment of the fish farm. Figure 22 identifies the more recent state of the land where it can be seen that the subject area proposed for the ADZ encompasses four habitat forms, namely:

- The paleo dune environment – the most leeward component of the site
- The stabilized slack or prograded beach system that lies within the paleo-dune slack
- The now stabilized, recent sand sharing system, comprising of various dune ridges and dry slacks
- The beach and intertidal environment

These differing eco-morphological environments have given rise to differing habitats as depicted in Figures 21 and 22. Figure 23 also identifies 5 sample points where floral species were recorded over transects of 60m on a presence-absence basis. A list of species recorded is attached in Annexure B, however, Figure 24 below, shows a graphic representation of all species located across the subject site.

4.4.1 Floral communities

Interrogation of Figure 24 provides some insight into the habitat form and structure of the study area, encompassing the three eco-morphological landforms presented above. Notable from this data is;

- 6 species are to be considered to be ubiquitous across the site ; *A kosiensis, B discolor, C equisetifolia,, C monilifera, C dactylon* and *E curvula.*

- Of these species, *A kosiensis, B discolor* and *C monilifera* can be considered to be endemic species associated with early forest seral states, following disturbance of coastal environments.

- *C equisetifolia* is an exotic tree with a tendency to invade areas following disturbance. In the case of the ADZ, the specimens located on site are representative of relic mature specimens planted in the 1950s, as well as saplings that have established through natural propagule dispersion mechanisms.

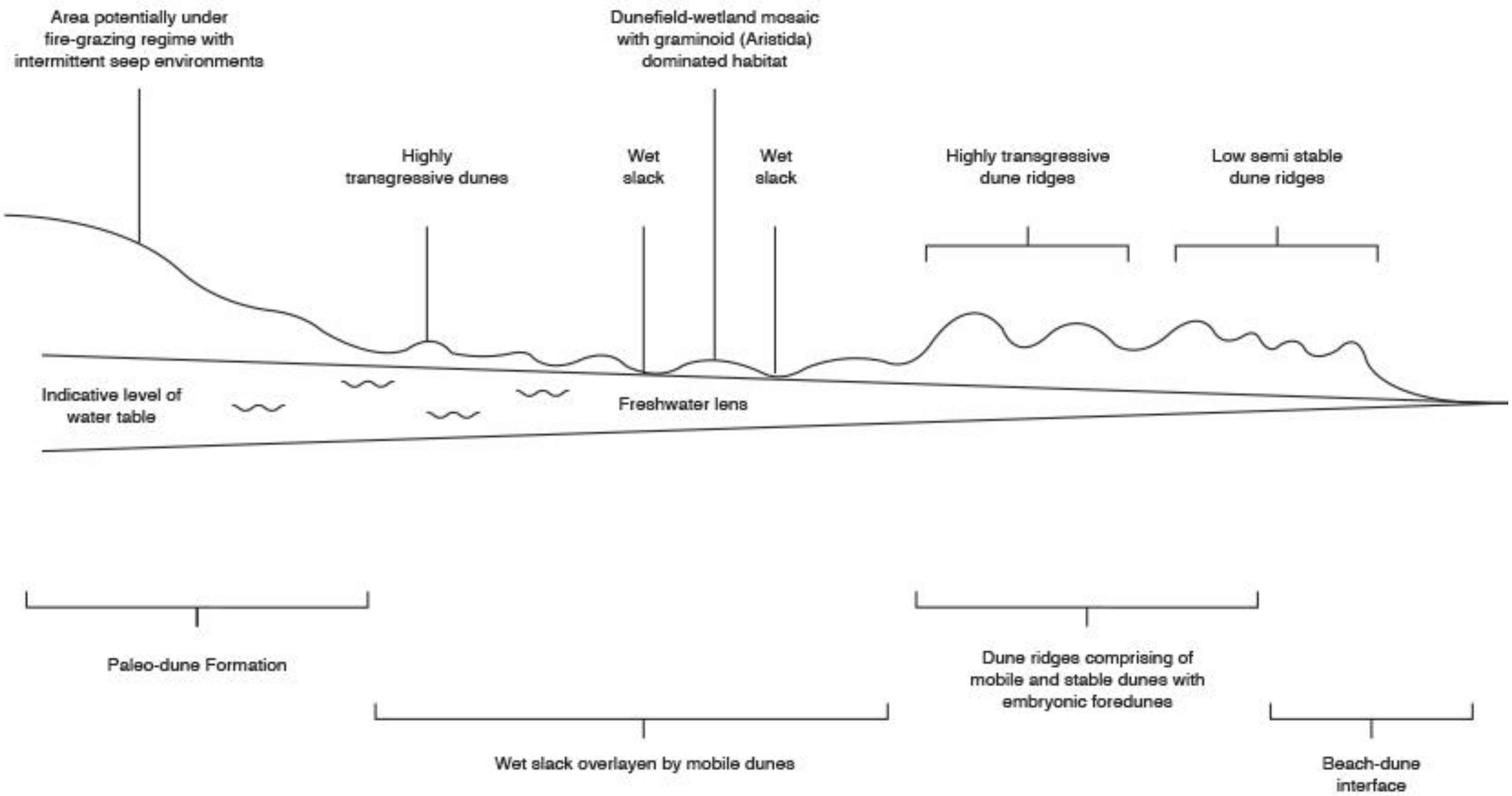

Figure 21. Stylised cross section of the site of the proposed Amathikhulu ADZ, prior to disturbance and anthropogenic interventions in the 1950s, indicating the various eco-morphological habitats that lie between the beach and the western paleo-dune environment. Note the position of the water table which may have been uncovered at times with dune transgression.

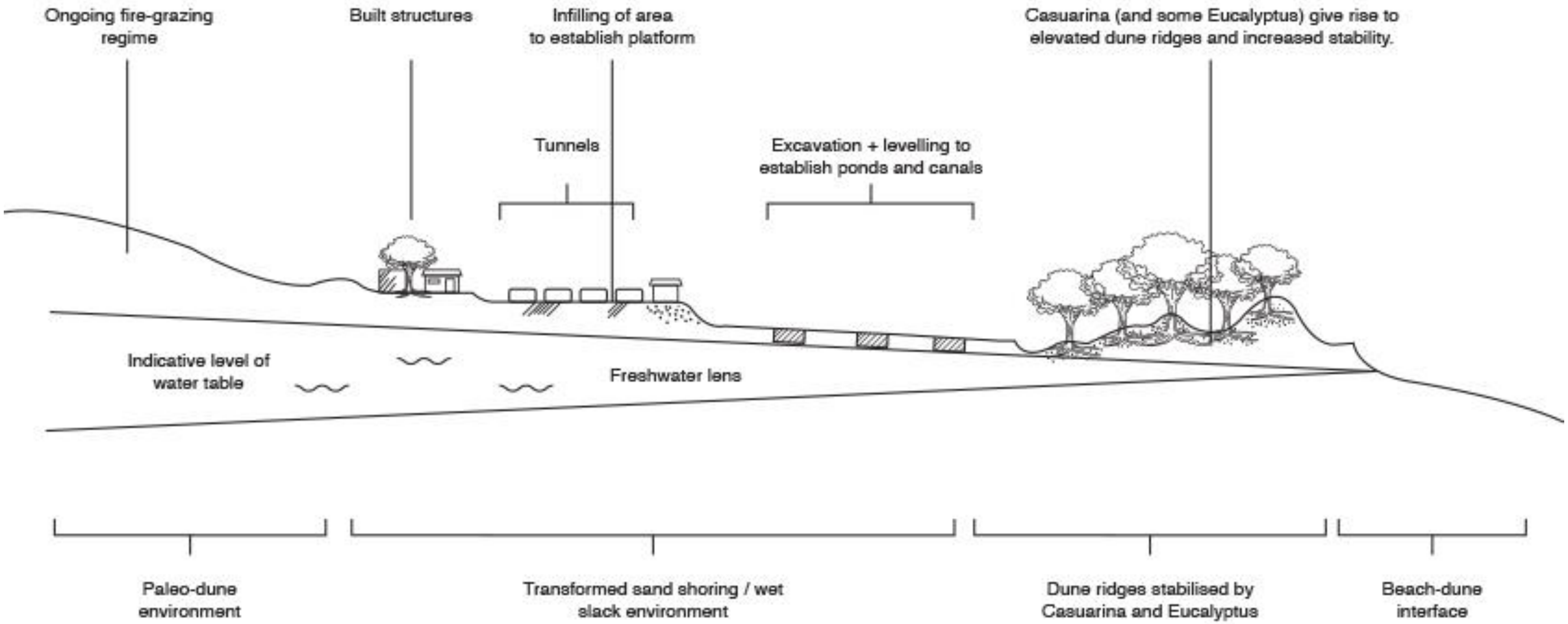

Figure 22. Stylised cross section of the site of the proposed Amathikhulu ADZ indicating the various activities and land use change as well as eco-morphological habitats that have arisen subsequent to the 1950s. Note deep excavation of ponds to intersect with water table.

Figure 23. Image indicating four habitats present within the site of the proposed ADZ.

- *A kosiensis* arises at points that are not subject to inundation by water but disturbance has arisen on the site. At points, this tree forms dense impenetrable stands.

- *C dactylon* and *E curvula* are graminoids (grasses), which within this coastal environment are indicative of ongoing disturbance (such as fire or grazing) or some level of inhibition within the succession process brought about by physical factors (e.g sand engulfment, anthropogenic factors).

- A number of other species dominate within specific morphological points within the landscape. *A junctiformis* is the dominant grass within the former ponded regions, with dense stands of *J kraussi* also being evident.

- Site 4, the recent dune ridges, shows the highest diversity across the site, primarily because of the influence of aspect, elevation and variable levels of plant-water relations

These varying habitats are discussed in more detail below.

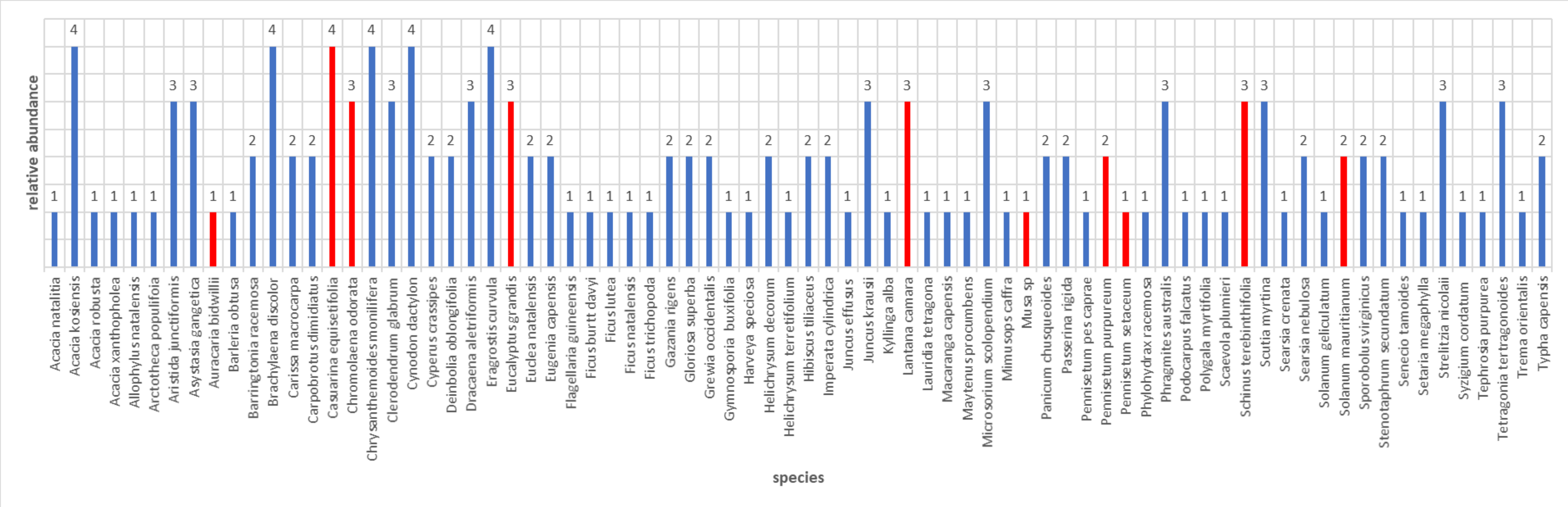

Figure 24. Graph indicating species recorded from sample points across site and the relative abundance /prevalence of such species. Red bars denote exotic species.

4.4.3 The paleo dune environment

The paleo dune environment lying to the west of the proposed ADZ (see Figure 23), comprises of primarily secondary grasslands dominated by *Aristida junctiformis*. The area in general has been subject to settlement and as a consequence of this, fire (burning of the veld to promote grazing for cattle) and livestock grazing are the predominant drivers of this graminoid habitat. While this area is not proposed for inclusion into the ADZ, the area is of importance for two reasons, these being;

- The area forms the catchment of a small drainage feature that runs shore parallel to the west of the ADZ. This stream is an important hydrological link to the "slack" environment that lies to the east of the present fish farm. Discussion on this and the broader wetland / hydrological environment is presented below.

- The area in general, is part of the broader groundwater recharge zone for the wet slack that lies to the east. Changes in this environment may have some influence on the nature of the freshwater associated with the dune slack or available groundwater.

It follows that this region is of importance to both the eco-morphological state of the more leeward, coastal environment on the north banks of the Amathikulu River, as well as perhaps the operations of the ADZ.

4.4.4 The leeward slack

Much of the dune slack and prograded coastline within the ADZ study area has been significantly transformed. The leeward components (in and around sample site 1 (see Figure 23), in general lies upon a large platform subject to cut and fill operations, and as stated above, comprises of a mix of stabilized aeolian sands and infilled materials (Figure 25). Figure 25 indicates a recent excavation within this area, where the aeolian sands have been exposed by trenching confirming the nature of the land in question.

While the present location of the tunnels and administration offices, as well as the "dog chew" manufacturing shed, may show some level of diversity, this area can be considered to be highly transformed both in terms of its morphological character and by virtue of the fact that much of the floral community within the area has been subject to horticultural practices.

Species common to this portion of the site include a number of exotic horticultural species including *Coleus* spp, as well as *Delonix regia*, while planted and secondary species are also common including the pervasive *Acacia kosiensis* and *Ziziphus mucronata*. Of significance within the area are a number of *Podocarpus falcatus* (yellowwood), and emergent *Ficus trichopoda* and *B racemosa*. These trees are listed within the Provincial Conservation Ordinance and the National Forest Act, however their significance within the broader ecology of the subject area is limited. Numerous specimens of *Ficus* spp are evident within the site, often used for screening of structures (Figure 26.)

In and around sample site 2, the infilling of the transgressive, wet slack has resulted in the establishment of a significant mono specific association of *Acacia kosiensis. A kosiensis* is the primary seral species within disturbed areas within the locality and this species has benefitted from the elevation of the site with infilling at this point, together with the proximal availability of surface and sub surface freshwater.

Figure 25. Image of excavation adjacent to existing hatchery operations. Not aeolian sands at depth within trench.

Within the *A kosiensis* association, some *suffrutex* species are evident including *Z mucronata* and the scandent *Smilax kraussii* (Figure 27). Some invasion, particularly by *Lantana camara*, arises where competition from *Acacia* is reduced. While floral diversity is low at this point, the area in general has not been subject to significant invasion by the pervasive *C equisetifolia* and probably offers refugia for larger local fauna.

Figure 26. Image of portion of site showing buildings and the presence of horticultural/landscape specimens of *Ficus natalensis*.

Figure 27 *A kosiensis* community near infilled areas forming a platform.

4.4.5 Emergent wet dune slack environment

To the north of sample site 2, upwards of 20 “grow out ponds” have been established and subsequently abandoned. These ponds cover an area of nearly 8 ha and extend between the existing buildings and the heel of the transgressive dune ridge. The excavations are an estimated 3m in depth and in some cases, ponds exceed an area of 1000m^2. A singular large canal bisects the ponds and still serves as a drainage canal for the present operational component of the facility, disposing of freshwater into a wide pond located near the heel of the dune cordon.

With the abandonment of these ponds deeper ponds have reverted to primarily *Typha capensis* dominated sedge communities, although *Periscaria senegalensis* appears to be common at points. Where surface flow is sustained *Phragmites australis* is the dominant floral association, however in deeper, aquatic environments, *Nymphaea nouchali* and *Lemna* spp. are evident. Some of these aquatic plants may be associated with the aquatic plant production and other operations within the aquaculture project and are naturalized within the area.

Figure 28. Excavated pond near heel of dune cordon which receives discharged water from aquaculture facility

The significant transformation of the dune slack has effectively rendered this area as a semi natural wetland environment, as surface sands have been removed and the sub surface water table has been exposed across the area through excavation. Compaction of areas has also arisen, giving rise to a mosaic of temporary wetland environments (Figure 29). These temporary wetland areas are dominated be primarily by the sedge, *J kraussi*, with *Cyperus esculentus* and *Mariscus macrocarpus* during the wetter periods, however the graminoids, *A junctiformis, S secundatum* and *Eragrostis* spp are common the site and are probably the dominant flora during the drier periods. Notably the graminoid parasite *Harveya speciosa* is also common within this area.

Figure 29. Compacted platforms within former slack environment form points where temporary ponding of water arises, leading to the presence of sedges and other hydrophytes. Grazing by cattle also arises in this area.

The presence of this wetland slack provides a local resource in the drier months for the grazing of cattle within this area. Also present within the slack is the exotic tree, *Eucalyptus grandis*, which has been planted as a commercial initiative and to lower the water table within the slack. (Figure 30). From a commercial perspective, the planting of *E grandis* in this area is perhaps the only viable land use that could have been employed from an agricultural / silvicultural perspective. The ecological ramifications resulting from the planting of *E grandis* cut across the eco-morphological and geohydrological status of the site. Their subsequent removal may offer some improvement in the two abovementioned ecological drivers.

The "wetland" environment that lies within the dune slack is to be considered a transformed system. The surface waters evident at points have emerged in part, through the stabilisation of the frontal dune cordon and the creation of the aquaculture grow out ponds, that lie to the lee of the site. Should the disposal of water from the aquaculture facility cease much of the surface hydrology and habitat associated with the area would change. If, additionally, the dune cordon were to tend towards a more transgressive form much of the habitat in this area would be transformed to a more mesic, coastal environment.

Figure 30. Image of *Eucalypt* spp established to the north of the existing aquaculture facility.

4.4.6 The dune cordon

The frontal dune cordon, which comprises of a series of dune crests (ridges) and swales, extends seaward of the dune slack for approximately 250m. The dune ridge comprises of recently established aeolian sands, stabilized by the planting of Casuarinas in or around the 1950s (see Figure 16 above), which have subsequently given way to secondary dune forest species, including *B discolor*, *A natalensis* and *C monilifera*. At points of increased transgression species such as *C dimidiata* and *E capensis* become more prolific.

The stabilized dune form, proximal to the beach interface is undergoing significant transgression, a situation encountered across most of the south east African coastline (Bundy *et al* 2009). Transgression varies over differing temporal and spatial parameters, however it is clear that an average rate of 4.5m to 5m per annum is being recorded along transgressive coastlines. Cooper (1991), who considered the entire KZN coastline in the early 1990s, recorded at two nearby stations

(Amathikhulu – 15 and 16) a shoreline change of -9.00m and -10.00m respectively for the period 1978 to 1983. A rapid appraisal of the transgressive dune cordons between 2009 and 2017 indicates that some parabolic dune forms receded by 5.5m, which is in line with calculations identified for the approximately 200 kilometres of coastline that have been recently assessed along the KwaZulu Natal coast (Bundy 2016). Figure 31 below, shows an image of parabolic dunes located just north of the Amathikhulu River mouth, seaward of the proposed ADZ.

Figure 31. Parabolic dunes located within the dune cordon of the ADZ.

Parabolic dunes generally establish where there is destabilization of a portion of the foredune, normally through storm activity and this disturbance is aligned and coincides with *inter alia*, a stable or increasing beach sediment budget, a modal dissipative beach and a sustained onshore dominant wind regime, regularly reaching runs of more that 5-6m.s^{-1}. Such situation is evident at these points within the ADZ study area and it is clear that the parabolic dunes located at Amathikhulu are at the vanguard of a general increase in transgression and on shore recession of the dune cordon (Figures 32 and 33). From these images, what is evident is:

- Parabolic dune formation has increased significantly, with an approximate landward recession of 40m in 5 years, at some points.

- The dune cordon in general, has undergone increased transgression

- Hummock dune formation has increased between 2013 and 2014, suggesting an ostensibly stable or positive beach sediment budget, but perhaps one derived from the dune cordon rather than the littoral environment.

Figure 32. Image of dune environment showing foredune vegetation cover in 2013

Figure 33. 2017 image of dune cordon as depicted above with increased transgression along dune cordon.

The above state indicates that dune recession is perhaps the most significant ecological factor affecting Amathikhulu and the ADZ study area. Increasing dune transgression and recession may be due to a number of factors, including ;

- Sea level rise (Psuty 1988)
- Changes in surface and groundwater availability in and around the frontal dune cordon (Rosati 2010)
- Changes in meteorological and maritime factors (Davidson-Arnott 2010)
- The aging and senescence of the exotic timber plantations that were established to stabilize the dunes in the 1950s

With regards to the last factor, the longevity of a Casuarina tree is estimated at approximately 60 years (Pernas 2013). This would suggest that most specimens planted in the 1950s should be subject to age related senescence at this time. If recruitment of sapling Casuarina within the same area is hampered by physical factors, such as those mentioned above, then it is likely that the dune cordon is reverting to a physical state akin to that evident prior to the 1950s. Such a state will see increasingly mobile sediments within the 250m wide dune cordon, that may over a relatively short period of time impinge on the dune slack environment. Presently, it can be inferred that the high levels of surface water made available to the frontal dune via the abandoned grow out ponds and the discharge of water into the dune slack from the present operations, are playing an important role in maintaining improved water availability to plants on the frontal dune, thereby maintaining stability. Under a drier hydrological and meteorological regime, this situation may change and transgression will arise.

The above factor is considered to be the most significant issue requiring consideration in the establishment of the ADZ. The impending and expected increasing dune transgression should form the basis for the identification of a coastal set back line that is to be established seaward of the ADZ.

4.4.7 Wetland Environments

Given the above, it is clear that the only “true” wetland environment that can be identified within the subject area lies within the drainage line to the west of the ADZ and parallel to the access road to the present aquaculture facility. Consideration of the 1937 imagery allows for the inference of the wetland environments at a broader scale, at that time. Figure 34, depicts these areas. As can be noted, three valley head wetland seep systems arise from the Pleistocene dune form to the lee of the ADZ and serve a small, channeled valley bottom system that flows shore parallel towards the Amathikhulu estuary. The roadway both to the ADZ and the recreational node adjacent to the estuary have served to divert and impede surface flow in and around this system, effectively diverting the stream and constraining flow. Perennial flow is evident in and around the lower HGM and at points, channels have been established to facilitate flow. However, below and to the east of the access road to the ADZ, the stream dissipates into the dune and beach sands (See Figure 36). Other disturbances in the catchment, such as the planting of woodlots has probably also contributed to flow reduction within the system.

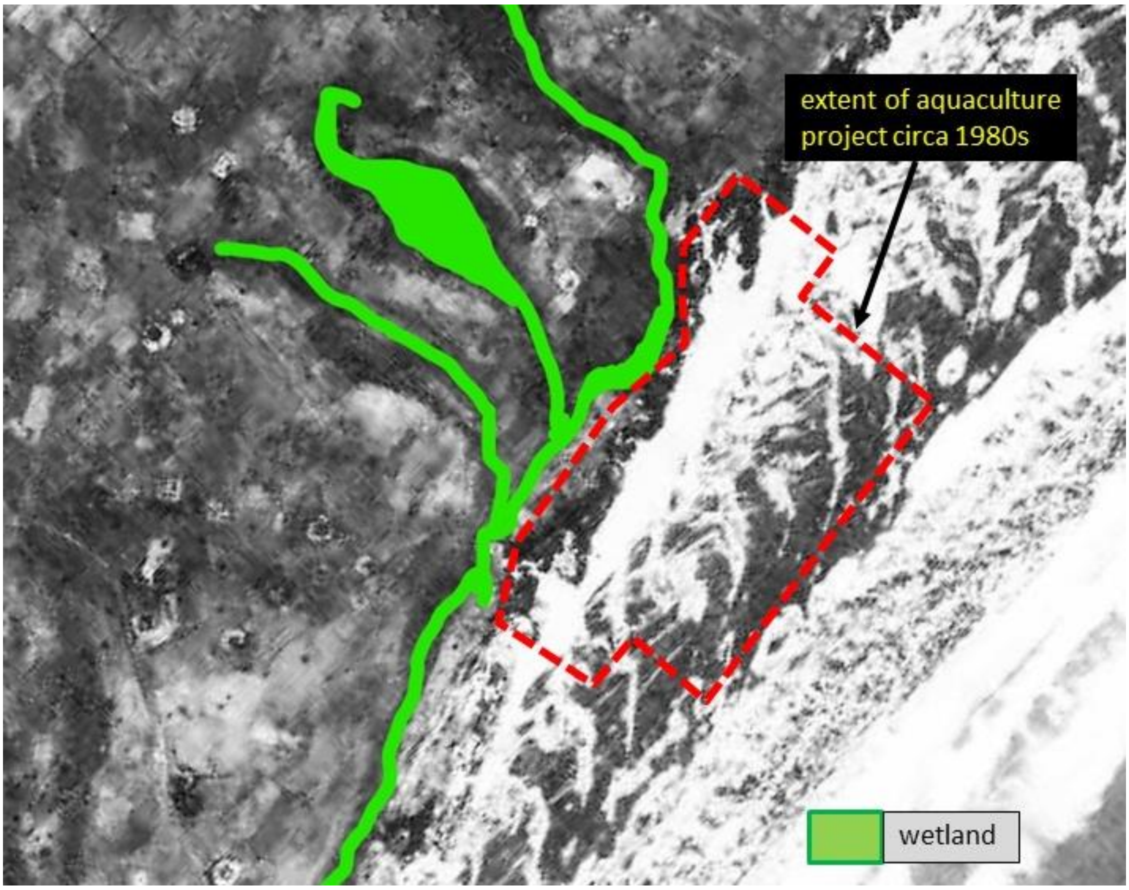

Figure 34. 1937 aerial image with implied drainage and wetland system at that time.

Figure 35. Image of upper portion of HGM lying adjacent to proposed ADZ and road access.

Nonetheless, the system does offer some important direct and indirect benefits at a local to regional level of consideration. While not evidently within the footprint of the ADZ, the system is likely to be subject to some level of disturbance arising from the project, particularly if there is a requirement to expand the project westwards or increase existing road infrastructure around the site. Figure 36 below indicates the ADZ and the wetland environments within 500m of the site, while Figure 37 indicates the various hydrogeomorphic units.

Figure 36. Present extent of wetland system showing that due to anthropogenic interventions, the system drains in the dune cordon

4 hydro geomorphic units (HGMs) have been identified within 500m of the ADZ (Figure 37). All wetland environments are associated with the catchment of an unnamed stream. Table 2 below, indicates the descriptive methodology for the classification of HGMs.

Table 2. Level 3 and 4 A wetland classification descriptions for the HGMs depicted in Figure 37.

HGM Identification	Description
HGM 1	*hillslope seep*
HGM 2	*hillslope seep*
HGM 3	*hillslope seep*
HGM 4	*channelled valley-bottom wetland*

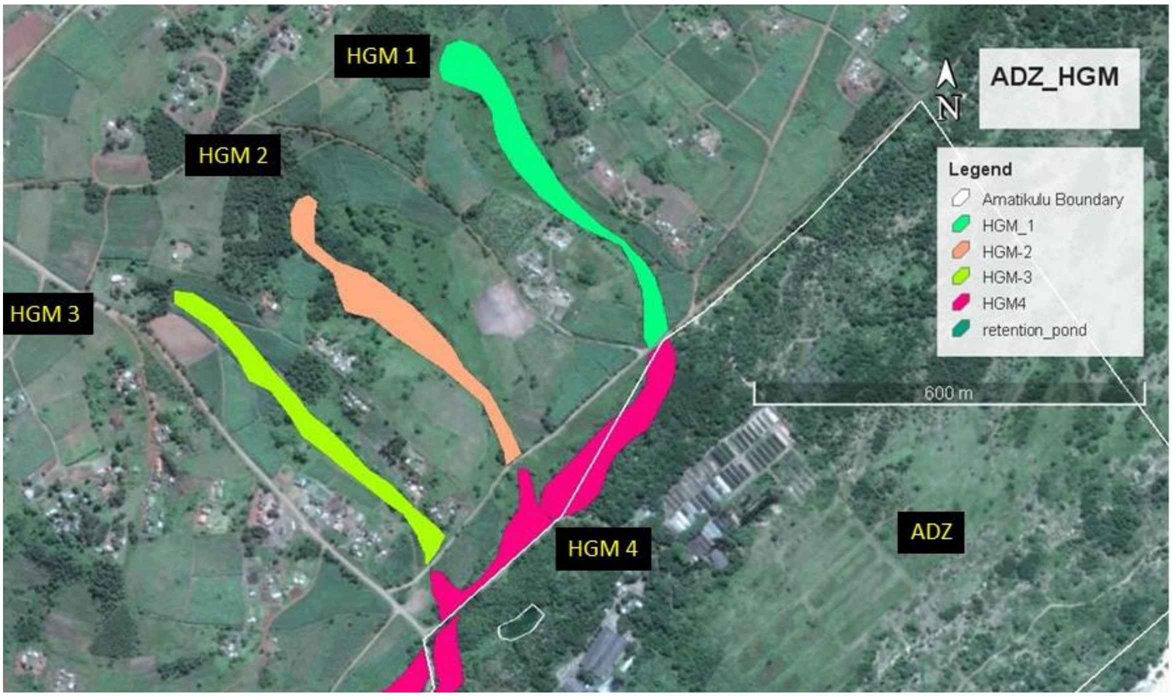

Figure 37. Map depicting 4 HGMs in relation to the ADZ.

HGM's 1,2 and 3 lie outside of and are elevated above the subject ADZ area on communal property within the Amathikhulu Reserve. These minor catchments will not be directly affected by the development of the ADZ. However, HGM 4 is likely to be affected by any activities relating to the upgrade to the access road. While further evaluation of the system will be required if there is a definitive requirement to upgrade infrastructure in and around the access road, an assessment of the functional state of the system will provide an indication of the perceived "value" of HGM 4. Using the methodology of Kotze et al (2007), HGM 4 was subject to a Level 2 assessment which entails the evaluation of certain identified "eco-services" provided by the wetland system.

In total 15 eco-services (e.g. nutrient removal, phosphate removal etc.) were evaluated and an eco-services score was calculated for each service. This score indicates the level of benefit (service) offered by the HGM unit and is ultimately an indication of the HGM's (or "wetland's") functional status. During the scoring process, criteria were scored as follows:

0 = Low	1 = Moderately Low	2 = Intermediate
3 = Moderately High	4 = High	

Table 3 below, provides the classes for determining the extent to which a "functional benefit" is provided.

Table 3. Classes for determining the possible extent to which a benefit is being supplied. The score represents the overall score for each benefit, e.g. flood attenuation (Kotze *et. al*. 2007).

Score:	**<0.5**	**0.5-1.2**	**1.3-2.0**	**2.1-2.8**	**>2.8**
Rating of the likely extent to which a benefit is being supplied	**Low**	**Moderately Low**	**Intermediate**	**Moderately High**	**High**

4.7.1 Brief Description of HGM 4

HGM 4 comprises of a shallow valley that in effect formed part of the dune slack that lies leeward of the Recent sand sharing system described above. The slack is underlayen by Pleistocene sands (Berea Red Formation) but receives to sub surface flow that arises from three hillslope (valley head) wetland systems (See Figure 37). Eco-morphologically, the system may be typified as a classic "moist dune slack" (Ranwell 1972), where fine grained, aeolian sands of marine origin (primarily silicas) have settled, that serve to retard percolation, relative to the more seaward coarse sediments, while humic and occasional clay lenses in the system serves to establish a seasonal wetland environment. At points of anthropogenic intervention, particularly where infilling or excavation has resulted in the retardation of flow, permanent, semi-natural wetland environments arise.

A qualitative review of the 5 components evaluated within a wetland functionality assessment for this HGM is provided below.

Geomorphological / Physical Function : The HGM has been constrained centrally, primarily as a consequence of the construction of semi-formal access roads, with minor crossings and some diversion and excavation. From a geomorphological perspective no flood terrace is evident primarily on account of the lack of surface flow within the system. Broadly, most of the HGM is subject to informal agricultural activities leading to the excavation of channels to facilitate drainage. Hygrophillous vegetation, primarily *Typha capensis* and *Barringtonia racemosa* is evident within the system, including the dwarf papyrus, *Cyperus prolifer*. Within the most seaward extent of the system, the presence of *Phoenix reclinata* and *Rauvolfia caffra* is indicative of improved plant-water relations (Figure 38).

Figure 38. Image of lower point of wetland showing *R caffra* and *P reclinata* in foreground

Aquatic chemical function : Surface water is generally absent from the system, except where trenching and ponding arises through excavations in the upper reaches of the drainage feature. As such, limited aquatic chemical function arises within the system, due primarily to the seasonal nature of the system and the vacillating water sub surface levels. A core sample within the drainage feature lying within the sand sharing system indicates increased humic levels and some deposition of materials, however the aeolian marine sands show high percolation rates and no evident mottling (Figure 39), indicating that conditions giving rise to geohydromorphic states are not present within this area – a situation typical of dune slacks.

Erosion control and surface water management. This seasonal wetland system offers limited erosion management opportunities on account of the small scale catchment, its topographic position and the percolative nature of the surrounding soils. Carbon sequestration is also limited on account of the transformed ecology of the area, inert nature of the soils and regular disturbance.

Socio-economic and Economic Beneficiation : The wetland system offers moderate beneficiation at an economic and socio-economic perspective, on account of its use for informal agriculture and, in particular, winter grazing. As a generally rural area, this opportunity is significant.

Figure 39. Core sample from lower reaches of HGM 4 indicating generally aeolian, silica and feldspar dominated sands with no evidence of geohydromorphic conditions.

Social and Recreational Value: The system offers some aesthetic value on account of the prevailing tourism focused activities that are associated with the Amathikhulu estuary.

Given the above, Fig. 40 below indicates the overall functional state of *HGM 4*. An overall "score" of 1.29 was achieved by this system allowing for its categorization as "*moderately low*" to "*intermediate*". It must be noted that the wetland functionality methodology as applied is an indicative scoring system and is highly skewed towards anthropogenic beneficiation. However using the results depicted in Figure 40, the system offers significant aquatic chemical beneficiation which may prove important from the perspective of the broader estuarine health of the Amathikhulu estuary. While not identified, primarily because it does not feature in the "wetland functionality model", the system, is also a significant stabilizing agent in respect of the proximal dune cordon. As explained above, this wetland and other freshwater delivery mechanisms, serve the frontal dune cordon at Amathikhulu via the freshwater lens, thus promoting a more verdant botanical cover in the region. Disturbance to the system should be subject to thorough, specific evaluation.

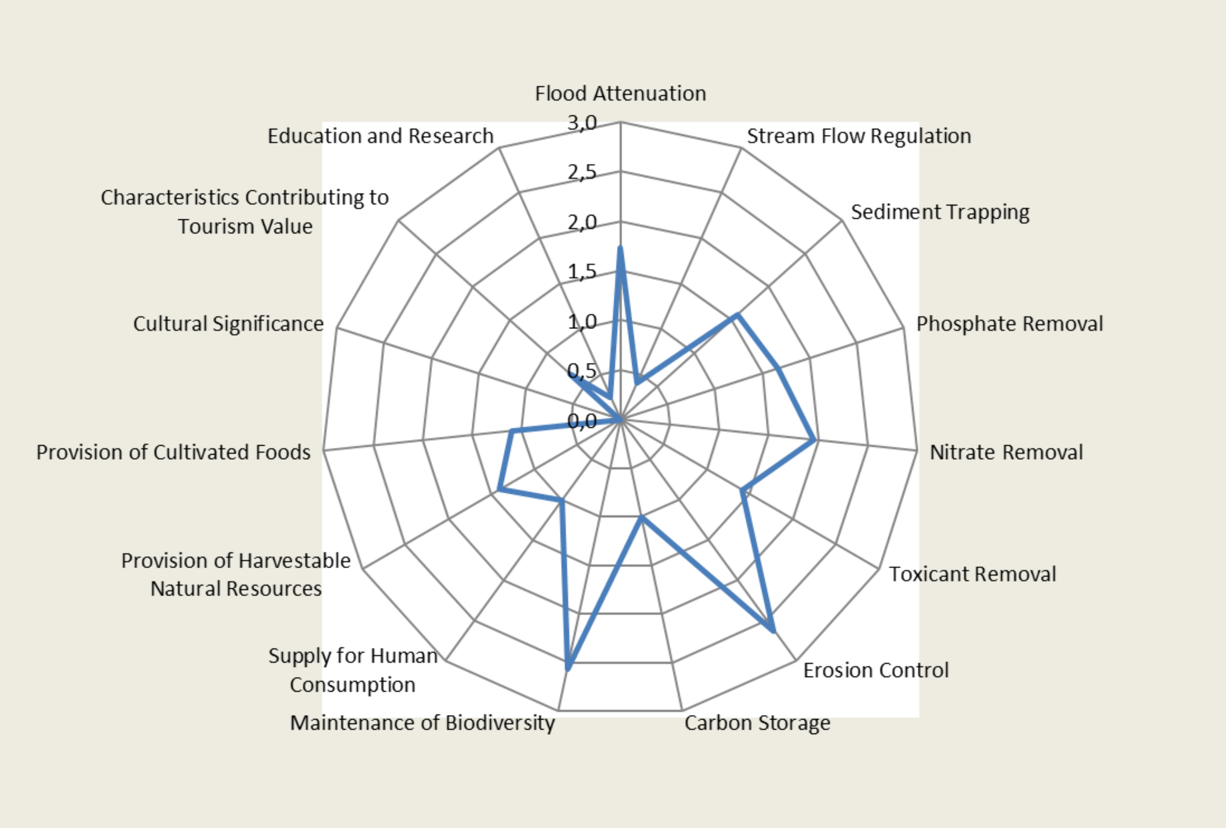

Figure 40. Ecoservices chart for channeled valley bottom wetland at Amathikhulu.

4.5 Fauna

Fauna that are endemic to the Amathikhulu region are considered to be typical of the central coastal environments of Kwa Zulu Natal. As indicated above, the ADZ and surrounds have been subject to a high level of transformation, including the introduction of an almost, annual fire regime, human settlement, changes in habitat form (e.g. transgressive dune to *Casuarina* plantation) and other influences. As a consequence of such change, much of the larger fauna that may have been present in the region in or around the early 1900's has been ousted from the region (McCracken 2007). Some species, such as common duiker (*Sylvicapra grimmia*) and steenbok (*Raphicerus campestris)* , genet (*Genneta tigris*) and mongoose, which are able to adapt to increasing human presence and transformed environments, do however remain present within the area. The proximal Amathikhulu Nature Reserve and other protected areas act as potential refugia to terrestrial vertebrates and invertebrates which may move from within the confines of these protected areas into areas around the ADZ.

The ADZ study area, due to its topographic variation and evidently high level of water discharge into the dune slack, offers an altered, but nonetheless suitable habitat for many terrestrial species, including smaller mammals, anurans and birds. The site in general is accessible to most species, not being cordoned by fencing in any manner and forming part of a north-south corridor link between the more northerly Siyaya system and the uMlalazi Nature reserve and the Amathikhulu River and its associated nature reserve. Table 4 below, indicates a preliminary checklist of terrestrial vertebrate species that has been compiled, based on local observations on site, historical observations and accounts and association of species with the prevailing habitat. It follows that species identified in the table can be considered to be found within the site with a high degree of certainty ("high likelihood of presence"), moderate level of certainty ("high likelihood") and lower level of certainty ('possible likelihood"). Those that are confirmed to be within the area either through visual observation or observation of spoor, spat or other indicators, are indicated as such.

Table 4. Preliminary checklist of terrestrial vertebrates with indication of likelihood of presence within the subject area

Species	**common name**	**Association with site**	**Conservation status**
Mammals			
Sylvicapra grimmia	Common duiker	present	
Philantomba monticola	blue duiker	likely presence	
Cephalopus natalensis	red duiker	possible presence	
Raphicerus campestris	Steenbok	likely presence	
Tragelaphus scriptus	bushbuck	present	
Genetta tigrina	large genet	present	
Aonyx capensis	Cape clawless otter	high likelihood of presence	
Felis serval	serval	possible presence	
Poecigale albinucha	striped weasel	likely presence	protected
Amblysomus hottentotus	Golden mole	present	
Procavia capensis	rock dassie	high likelihood of presence	
Lepus saxatilis	scrub hare	high likelihood of presence	
Potamochoerus porcus	bushpig	present	
Otolemur crassicaudatus	thick tailed bushbaby	possible presence	
Cercopithecus aethiops	vervet monkey	present	
Hystrix africaeaustralis	porcupine	present	
Galerella sp	slender mongoose	possible presence	
Ichneumia albicauda	white tailed mongoose	high likelihood of presence	
Mungos mungo	banded mongoose	present	

Atilax paludinosus	water mongoose	present	
Herpestes ichneumon	large grey mongooese	high likelihood of presence	
Cryptomys hottentotus	common mole rat	likely presence	
Graphiuris murinus	woodland dormouse	possible presence	
Thryonomys swinderianus	greater can rat	present	
Crociduria mariquensis	swamp musk shrew	likely presence	
Crociduria flavescens	red musk shrew	possible presence	
Petrodromus tetradactylus	four toed elephant shrew	possible presence	
Aethomys chrysophylis	veld rat	possible presence	
Lemniscomys rosalia	single striped mouse	high likelihood of presence	
Mastomys natalensis	multi mammate mouse	high likelihood of presence	
Mus minutoides	pygmy mouse	likely presence	
Dasymys incomtus	water rat	likely presence	
Dendroimus melanotis	climbing mouse	possible presence	
Otomys angoniensis	Angoni vlei rat	likely presence	
Rattus rattus	house rat	high likelihood of presence	
Steatomis pratensis	fat mouse	possible presence	
Tatera leucogaster	bushveld gerbil	likely presence	
Hipposideridae	leaf nosed bats	possible presence	
Molossidae	free tailed bats	present	
Nycteridae	slit faced bats	high likelihood of presence	protected
Rhinolophidae	horseshoe bats	possible presence	
Vepertionidae	vesper bats	possible presence	
Reptiles			
Acontias plumbeus	giant legless skink	high likelihood of presence	
Agama sp	agama	likely presence	
Bradypodion melanocephalum	black headed dwarf chameleon	likely presence	protected
Bradypodion setaroi	Setaro's dwarf chameleon	likely presence	protected
Bitis arietans	puff adder	likely presence	
Bitis gabonica	gaboon adder	high likelihood of presence	protected
Chamasaura	grass lizards	present	
Chameleo dilepis	flap necked chameleon	present	
Dendroaspis angusticeps	green mamba	high likelihood of presence	
Dendroaspis polylepis	black mamba	high likelihood of presence	
Dasypeltis	egg eaters	high likelihood of presence	
Hemidactylus mabouia	tropical house gecko	high likelihood of presence	

Mabuya capensis	Cape skink	high likelihood of presence	
Mabuya striata	striped skink	present	
Naja mossambicus	Mozambique cobra	high likelihood of presence	
Naja melanoleuca	forest cobra	high likelihood of presence	
Python natalensis	rock python	high likelihood of presence	
Hemachatus	rinkhals	high likelihood of presence	
Macerlaps microlepidotus	Natal black snake	high likelihood of presence	
Lamprophis spp	house snakes	high likelihood of presence	
Lycodonomporphus spp	water snake	high likelihood of presence	
Leptotyphlops spp	thread snake	likely presence	
Typhlops spp	blind snake	likely presence	
Thelotornis capensis	vine snake	high likelihood of presence	
Geochelone pardalis	Leopard tortoise	likely presence	
Pelomedusa sp	marsh terrapin	likely presence	
Pelusios rhodesianus	Mashona terrapin	possible presence	
Trachemys scripta	Red eared terrapin	possible presence	
Amphibians			
Amietia anolensis	river frog	present	
Arthroleptis wahlenbergeii	shovel footed squeaker	high likelihood of presence	
Arthroleptis stenodactylus	bush squeaker	present	
Leptopelis mossambicus	brown backed tree frog	likely presence	
Leptopelis natalensis	Natal tree frog	present	
Breviceps verrucosus	Mocambique rain frog	likely presence	
Breviceps mossambicus	plantive rain frog	likely presence	
Amietophrynus gutturalis	guttural toad	present	
Amietophrynus rangereii	raucous toad	possible presence	
Schismaderma carens	red toad	high likelihood of presence	
Hemisus guttatus	spotted shovel nosed frog	likely presence	
Hemisus marmoratus	mottled shovel nosed frog	possible presence	
Afrixalus fornasinii	delicate leaf folding frog	likely presence	
Afrixalus delicatus	greater leaf folding frog	likely presence	
Afrixalus spinifrons	Natal leaf folding frog	high likelihood of presence	
Hyperolius marmoratus	painted reed frog	present	
Hyperolius pickersgilli	Pickersgills reed frog	likely presence	protected
Hyperolius pusillus	water lily reed frog	likely presence	
Hyperolius semidiscus	yellow striped reed frog	high likelihood of presence	
Hyperolius tuberilinguis	tinker reed frog	present	

Kassina maculata	red legged kassina	high likelihood of presence	
Kassina senegalensis	bubbling kassina	high likelihood of presence	
Phrynobatrachus natalensis	snoring puddle frog	likely presence	
Ptychadena mascariensis	plain grass frog	high likelihood of presence	
Ptychadena oxyrhynchus	mascarene grass frog	high likelihood of presence	
Ptychadena anchiete	sharp nosed grass frog	likely presence	
Ptychadena porosissima	striped grass frog	high likelihood of presence	
Strongylopus grayii	clicking stream frog	high likelihood of presence	
Strongylopus fasciatus	striped stream frog	high likelihood of presence	
Tomopterna natalensis	Natal sand frog	high likelihood of presence	
Xenopus laevis	common platanna	present	

From Table 4 it is evident that amongst the mammal species that are considered to be present within the site, most of these species are members of the Order Rodentia and Insectivora, which are often related to graminoid or sedge dominated habitats or are able to exploit transformed habitats. A number of smaller carnivores are likely to be present within the region including mustellids and the striped weasel (*P albinucha*). The Cape clawless otter (*A capens*is) is also likely to be present within the site and may under certain circumstances, prove to be a problem animal to large scale fish producers.

A number of reptiles are likely to be present, particularly members of the Order Squamata (snakes) with exploitation of both abundant rodent populations and the generally diverse but transformed habitat within the ADZ. The preliminary list of anurans or frogs that are likely to be present on site is indicative of a number of ecological factors that favour Anuran families (Figures 41 and 42). With generally high volumes of water available at points that vary from shallow ephemeral pans to deep excavations with permanent water, as well as varying vegetation communities ranging from graminoid to sedge dominated habitat, amphibian diversity on site should be considered to be “high”. Notable, is the high likelihood of the presence of *Hyperolius pickersgilli* which is found only in isolated patches of reed communities between Richards Bay and Durban, although recent findings have indicated that its range may be wider, but remains fragmented. This species is considered “critically endangered” and of high conservation significance.

The presence of sedge communities with available open surface water, offers a number of avian (bird) species forage and predatorial opportunities. Consideration of the SABAP 2 Pentad for this area (2900_3135 QDGC: 2931BA) indicates a species list of 254, recorded since 2004. Species listed within the pentad show a mix of species associated with coastal forest (Narina trogon- *Apaloderma narina*), estuarine and freshwater environments (Cape cormorant, reed cormorant and white breasted cormorant – *Phalacrocorax* spp) and grassland species (Cape and yellow throated longclaw - *Macronyx capensis* and

M croceus). It is likely that species such as Southern red bishop (*Euplectes orix*) will utilize much of the sedge habitat in the former grow out ponds as nesting sites, as will species such as red knobbed coot (*Fulica cristata*).

Figure 41. Image of *Amietia angolensis*, common to the region and the site of the ADZ.

Figure 42. Image of *Hyperolius tuberilinguis*, a reed frog evident in and around the grow out ponds

It is clear that further transformation of the ADZ will favour some of the locally extant fauna, while expansion of the development area and further transformation of already disturbed habitat (relic ponds) will serve to oust other species. Given the proposed development layout (Figure 3, above) it can be generally concluded that :

- Species reliant on sedge communities, particularly within the relic grow out ponds will be affected negatively by the re-establishment of these facilities, as suitable habitat is removed. Of particular consideration would be the loss of refugia associated with species such as *H pickersgillii* and *H tuberilinguis*.

- Avian diversity may benefit in general as areas of open water increase. Notably, species reliant upon sedge communities for nesting sites may be negatively affected by the ADZ.

- Some terrestrial mammals such as Cape clawless otter (*A capensis*) and piscivores in general, may benefit inadvertently from the establishment of the ADZ.

- Electrical light pollution (ELP) which is likely to be associated with some aquaculture operations at the site may serve to alter behavior or ethos within populations. Chiroptera (bats) are particularly vulnerable to changing localized light regimen (Kunz 1996).

- Depending upon the nature of aquaculture species being produced within the ADZ, specimens that may escape or find their way into the natural environment may affect the endemic fauna in a number of ways, changing population behaviours, acting as vectors for disease or simply ousting species from certain environments and habitats.

4.5.1 Exotic and invasive species

Exotic and invasive species presently found within the ADZ site are likely to be related to escaped species associated with the operations of the existing aquaculture project. The Amathikhulu fish farm has over a number of years produced a variety of ornamental fish which may have found their way into the nearby freshwater systems, particularly those open pits associated with the grow out ponds and the effluent water discharge. These fish may include:

Carassius auratus	Goldfish
Cyprinodontiformes spp	swordtails
Poecilia reticulata	guppy
Pterygolichthys disjunctivus	Sailfin catfish

Endemic fish that may still remain within the grow out ponds include African sharptooth catfish *Clarias gariepinus*, which may have arisen in these ponds as a consequence of introduction from the farming operations or may have invaded these ponds from other freshwater systems in the region. Koi, *Cyprinus rubrofuscus*, a highly bred species of carp are also likely to be present in waters that are present year round. Within the discharge point at the heel of the dune cordon (Figure 28), local fishermen advised that they catch tilapia (*Oreochromis spp*) which are likely to have arisen from the aquaculture operations.

The presence of a number of ornamental Gastropoda (snails) was identified at points around the drainage features of the site, including *Pomacrea diffusa*, the apple snail and *Gyraulus chinensis* (Ram's horn), which are potentially invasive molluscs. The quilted melania (*Tarebia granifera*) is likely to be present within open water systems. Species such as the above are a significant threat to freshwater systems and may find passage into systems such as the Amathikhulu River under suitable circumstances. These species may also prove problematic to aquaculture ventures in the ADZ if not controlled, particularly where their presence may act as a vector for parasites or alternatively they affect the functioning of pumps and other equipment.

5 IMPACTS AND MANAGEMENT OBJECTIVES

From the above, it is clear that the development of the ADZ at Amathikhulu is likely to reinstate or heighten the effects of historical transformation within the site. From a spatial perspective, it is evident that the proposed ADZ footprint will utilise land that has been subject to direct and indirect anthropogenic transformation over nearly 80 years. The impact of specific aquaculture operations within the ADZ are however unknown, as the exact nature of these operations is not yet available for consideration. What is evident is that in the operation of the ADZ it will be important to:

- Consider the source of water for aquaculture purposes and where required, the disposal point of such water. Where freshwater is to be disposed of, suitable filtration and means of neutralising organisms in effluent waters must be implemented, while a similar mechanism for saline waters will also be required. The recycling of waters is an option requiring further exploration.

- The placement of a marine intake and discharge pipe requires careful consideration. This should be situated to the north of the site as recommended above, however there are a number of latent and complex factors that must be taken into consideration to ensure a risk averse approach.

- The risk of alien flora and fauna escaping into the environment from the aquaculture production facilities is perhaps one of the greatest risks associated with the site, however this concern applies to all aquaculture projects where the product is not endemic to a region. Management interventions can be instituted to minimise this risk, however within the Amathikhulu ADZ the proximity of the Amathikhulu River and its associated estuary is of concern. This estuary is considered to be regionally of significant, being rated by Harrison et al (2000) as having "good" icthyological diversity and "good aesthetic" amenity. A risk – averse approach would see the institution of measures that include:

    - Water should not be drawn from the Amathikhulu estuary, nor disposed into the estuary.

    - Monitoring of the morphology of the north bank of the Amathikhulu estuary, water chemistry and estuarine bio-diversity of the system be instituted at an early stage, prior to the commencement of the ADZ. This will provide baseline information and act as an "early warning" system in respect of any untoward impacts that may arise on the estuary or river from the activities of the ADZ.

    - That any marine outfall established by the ADZ be positioned distal of the estuary taking into consideration the prevailing in-shore currents, as well as mouth dynamics.

    - Measures should be taken to prevent or reduce the transfer of propagules and other biotic material from the ADZ to other external aquatic and marine systems via vectors such as birds and terrestrial mammals. This may be accomplished *inter alia*, through the use of nets and tunnels that cover open water systems.

From the above, it can be stated that if sanctioned, the ADZ should implement a policy of review and assessment for each and every aquaculture operation within its confines, to identify and manage risk to the local environment that may arise from any particular operation. A risk-averse policy should be implemented whereby projects that cannot guarantee the limiting of any biological material to their operational space should not be approved by the ADZ management.

5.1 Ecological significance of the ADZ from a spatial perspective

Using the information presented above, a spatial plan indicating "ecological significance" and "ecological function" can be presented. This plan serves two purposes, these being:

- The identification of areas where biological diversity may be considered "significant", whether this be floral or faunal.

- The forecasting of coastal processes and the application of suitable safeguards that will allow for the maintenance of ecological function.

Figures 43 to 45 below, indicate:

1. Areas of ecological significance (Figure 43), which are based upon the state of the various habitat forms located within these areas, as described above. Effectively, these areas have been identified and delineated where;

    a. a *measured level of seral response* - in other words, succession, has arisen on site and a secondary habitat has established. These areas have been designated as areas of **moderate ecological significance**.

    b. *transformation has taken place with little seral process* - that is habitat that is presently subject to ongoing disturbance or where disturbance has been severe – such as the import and infilling of land or where existing buildings and commercial operations are in progress. These areas have been designated as areas of **low ecological significance**.

    c. *lands may have been subject to some levels of disturbance or transformation, but are functionally importan*t in terms of their bio physical state, be that in support of biological processes (e.g. the relic dune slack habitat) or through physical processes (e.g the dune cordon). These areas have been designated as being of **high ecological significance.**

2. Figure 44 indicates the coastal set back line. The Integrated Coastal Management Act (2009) identifies the objective of a coastal set back line as being to "protect and preserve". (ICM Act 24 of 2008 and its subsequent Amendment Act 36 of 2014). In addition, it is understood that more than one set back line may be identified, depending upon the nature of the coastline and the identified requirements for the conservation of coastal processes (DEDP Western Cape

2010). Furthermore, it is understood that an MEC (or Provincial Minister) identifies and promulgates the requirements for the identification and establishment of a coastal set back line following engagement with authorities and the public, whereupon the Municipality delineates such line. While no set back line or criteria for identification of a set back line has been promulgated by the Provincial authorities, given the nature of the Amathikhulu coastline, its rural setting and its present state where it is unencumbered by built structures, it is prudent to provide a draft coastal set back line that meets the requirements for development of the ADZ, going forward. In addition to the above, the set back line plays a functional role in the maintenance of various coastal processes, while it also acts to preserve infrastructure under varying climate change scenarios. This setback has been identified based upon the following;

a. Recognition of the increasing level of beach and dune erosion that has arisen along the KwaZulu Natal coast and more importantly, the rapid erosion that has arisen at Tugela Mouth, where over 90m of shoreline has been lost in a matter of four years. Such transgression is accompanied by the loss of built infrastructure and the concomitant landward movement of the dune cordon.

b. The line has been established to accommodate a 5,5m / annum retreat forecast over a period of 20 years - this aligns with methods applied in the United Kingdom for the placement of infrastructure on retreating coastlines (DEFRA 2001). A total set back from the dune cordon heel of 110m has been applied.

c. The set back accounts for a number of ecological processes, in particular the maintenance of sub surface geohydrology and the maintenance of a vegetated slack. It is to be recalled that much of the habitat within this area is reliant upon the continued disposal of water from the aquaculture development into the slack and areas proximal to the heel of the dune cordon. Nonetheless, as indicated above, the maintenance of a corridor, unencumbered by development, that runs shore parallel is considered to be of significance from an ecological landscape perspective.

3. Figure 45 indicates a recommended development footprint for the ADZ. This footprint takes into consideration the coastal set back line and those areas designated as being of “high ecological significance”. As such a development “footprint” of approximately 30 ha is recommended.

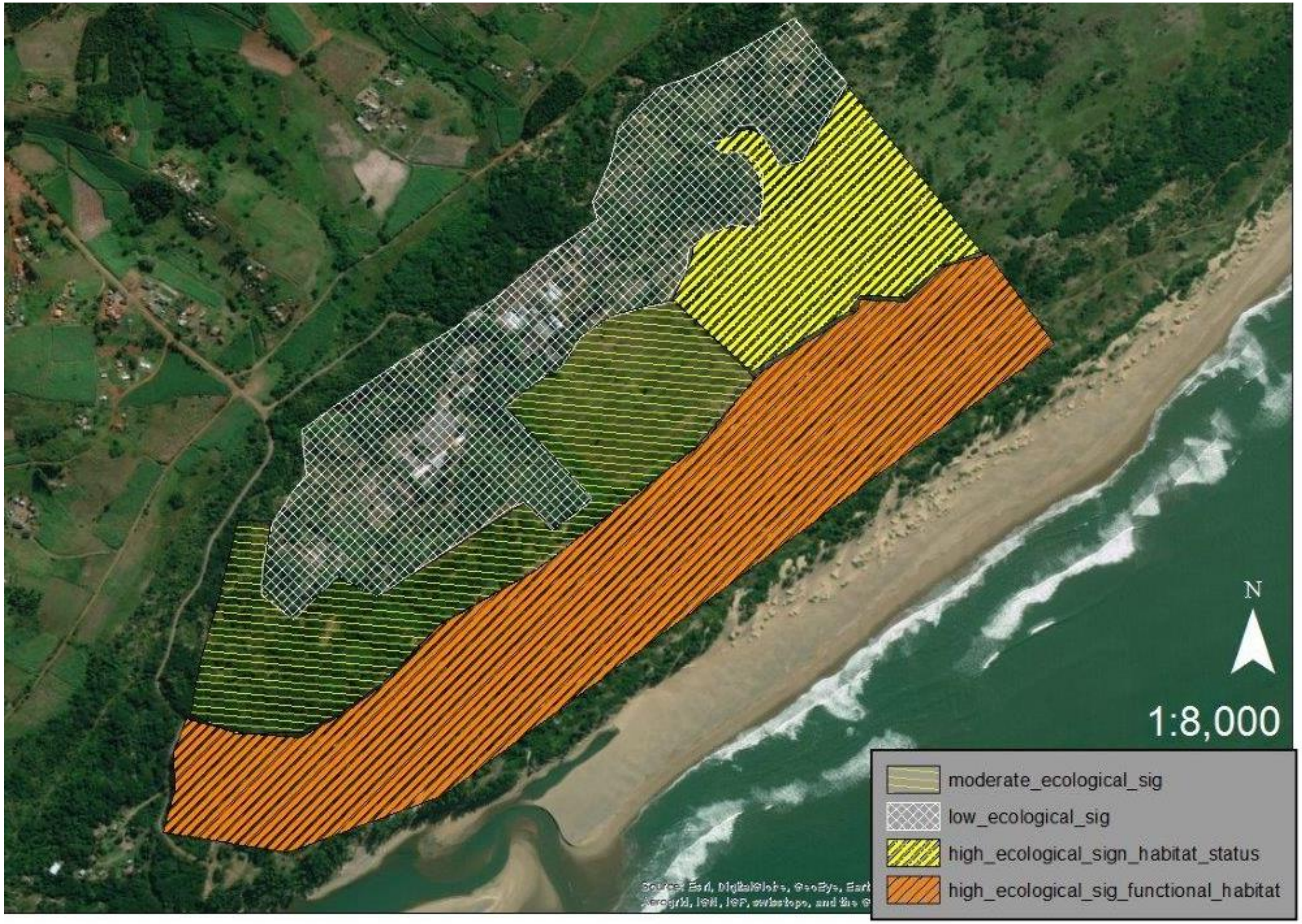

Figure 43. Map of ADZ indicating areas of differing ecological significance (“sensitivity”)

Figure 44. Coastal set back line for the Amathikhulu north bank as determined using ecological determinants

Figure 45. Map indicating proposed development footprint for ADZ.

Table 5 below, identifies on a qualitative basis, the forecast levels of impact that would arise on the terrestrial environments within the ADZ, should the development proposal proceed. The level of impact is derived using the following:

Spatial Extent: Denotes the affected area, - *site, local, regional or national*

Duration: The period of time over which the impact will be noted. This may be "*long term* (greater than the duration of project), "*medium term"* (occurs during the lifetime of the project) or "*short term*" (less than the lifetime of the project and primarily during the implementation stage of the project).

Probability: The likelihood of the impact occurring as a result of the project being undertaken. Such probability may be "*definite*", "*possible*" or "*unlikely*".

Significance: The nature of the impact in respect to the status quo (i.e. degree of alteration of present state). Such levels of severity may be "*high*", "*moderate*" or "l*ow*".

Status: This refers to the overall impact determined from the above parameters. The impact may be *negative* (a decline) or *positive* (an improvement or net beneficiation) from the status quo. The change may be considered to be the product of the above factors and indicates the level of impact

Confidence : An indication of the level of surety that the impacts or the parameters identified, will occur.

From Table 5 it is clear that given the available information, together with the transformed nature of the region in question, most eco-morphological environments within the study area will be subject to *low to moderate* levels of impact of a *negative* nature. However, within the relic dune slack, impacts will be considered "high" and negative, primarily on account of the transformation of the abandoned grow out ponds to areas of open water. Such activities will see a loss of primarily monospecific sedge communities (*Typha capensis*) with the concomitant establishment of open water environments which will alter the local ecology as both floral and faunal communities change in response to the re-establishment of these ponded open water systems. Mitigation of these impacts is however achievable, primarily through the retention of some of the relic grow out ponds and the maintenance of the dune slack to the north of the site. As such, the variable topographic morphologies discussed above may be preserved, maintaining a continuum of features in the dune slack.

Table 5 Review of impacts arising from the re-instatement of aquaculture projects within the Amathikhulu ADZ

Aspects	Spatial extent	Duration	Probability	Significance	Status	Confidence	Mitigation
Paleo dune environment	Local	Long term	Definite	**Moderate -ve**	High	High	The development footprint of the ADZ should lie within the identified transformed habitat as indicated in Figure 46. Further excavations which impinge upon the prevailing water table should be avoided. Ensure that wetland system located to the west of the dune slack is managed and maintained as a conservation area. Any alteration of the present access route to the ADZ, which impinges upon the present crossing should be subject to evaluation and consideration to ensure that hydrological processes and maintained and where possible, improved.

Aspects	Spatial extent	Duration	Probability	Significance	Status	Confidence	Mitigation
Dune slack Environment	Regional	Long term	Definite	**High -ve**	High	High	The identified coastal set back line should be sanctioned and recognized by the ADZ management. The coastal set back line allows for the maintenance of eco-morphological connectivity between the north and south of the coastline. Relic grow out ponds should in part be retained particularly on the seaward extent of the site. Proposals to limit or end the discharge of waters from the aquaculture project into the present disposal channel should be subject to specific consideration. Such consideration should give due consideration to the impact on the dune cordon. The removal of *Eucalyptus grandis* (and other exotic vegetation) within the dune slack should be undertaken in this region. The removal of *C equisetifolia* may also be considered following specific review of the impacts of the wholesale removal of these trees.

Aspects	Spatial extent	Duration	Probability	Significance	Status	Confidence	Mitigation
Dune cordon	Local	Long term	Possible	**Moderate**	-	High	Coastal set back line and recommended development footprint is to be maintained Incursion into the dune cordon to be subject to specific review. If required, the establishment of intake / outfall pipes into the sea should follow an alignment that ensures that the eco-morphology of the dune cordon is generally maintained in an undisturbed state i.e. avoidance of significant excavation and disturbance If dune transgression is to be moderated, it will be important to maintain a level of freshwater disposal into the dune heel. The removal of exotic vegetation on the dune cordon should be considered, subject to specific review and consideration of the impacts of its removal on the ADZ.

Aspects	Spatial extent	Duration	Probability	Significance	Status	Confidence	Mitigation
Supra – aerial **Inter – tidal** **Environment**	Local	Long term	Possible	**Low** **-ve**	Low	Low	Intake and discharge pipes associated with the ADZ, if required, should be positioned within the coastal environment to the north of the ADZ. The exact position and the nature and design of these structures should be subject to specific evaluation in order to ensure that impacts of a bio-physical nature are moderated. Discharge waters from the ADZ should be subject to a sanitation process which ensures the neutralization of any biotic material. The use of ozonisers, ultra violet light or other methods should be considered. The ADZ, in conjunction with authorities, should determine the chemical standards of water for disposal using the SA Marine Water Quality Guidelines or similar standards. A policy of *no loss of live biotic material* from the ADZ into the ambient environment should be adopted by the ADZ.

6. CONCLUSION AND MANAGEMENT INTERVENTIONS

The coastline, between the Amathikhulu River and Mtunzini town can generally be described as being relatively undisturbed, lying within a rural environment. One area of exception is the site of the proposed aquaculture development zone (ADZ), which lies to the immediate north of the Amathikhulu River. This particular stretch of coastline has been subject to a number of anthropogenic interventions, particularly in a bid to stabilise the transgressive, prograding dune field that lies within the coastal frontage. Following this initiative, the area was also subject to significant land use change, with the advent of the Amathikhulu Fish farm which was established in the 1980s.

The proposed ADZ for the area is in essence, taking advantage of the existing infrastructure found within the site, as well as the strategic position of the site, this being in close proximity to the sea and a source of marine waters, with evidently, consistently available freshwater. It can therefore be stated that the proposed site has been subject to significant levels of transformation over a period of 80 years, with the present ADZ proposal looking to exploit this transformed area.

Howsoever, since the abandonment of portions of the Amathikhulu Fish farm, two factors have come to the fore in respect of the site, namely; an evident transformation in the immediate and regional coastal environment, where coastal erosion and dune transgression have become rapid and significant and bio physical changes and seral advancement within some portions of the abandoned lands has given rise to relatively diverse, “semi-natural” but eco-morphologically functional environments.

Using data obtained from site reconnaissance, historical imagery, as well as other forms of evaluation, a development footprint for the proposed ADZ has been identified that accommodates eco-morphological processes and other factors in and around the ADZ site, while also forestalling any damage to infrastructure that may arise from coastal recession.

The identified development footprint presents a spatial representation of the extent of the ADZ that may be utilised without undue ecological impacts arising. However, given the fact that the nature of activities within the ADZ are generally unknown, both in terms of the technology that is to be employed and the nature of the products arising therefrom, impacts and ecological risks associated with each aquaculture activity should be subject to specific review prior to implementation. A number of key management interventions are proposed that reduces the risk of the operations of the facility to the ambient environs at Amathikhulu.

With the above in mind, the recommended footprint for the ADZ, as described, is proposed as an opportunity to utilise existing aquaculture infrastructure whereby eco-morphological impacts are minimised while at the same time, a key agro-industrial sector of the economy is allowed to develop. The identified footprint is recommended for sanction by the relevant authorities.

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