Current Status and Management Options for Salmon Hole/Post Office Rock Beach

Report prepared for the Wattle Range Council

by

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EXECUTIVE SUMMARY

The recent history of erosion at Post Office Rock- Salmon Holes Beach is briefly reviewed. Previous analyses of the photographic imagery and a review of the more recent topographic profile data indicates that the erosion rate has slowed in the period 2009 to 2017 compared to the 2001 to 2009 period. Erosion rates were 15,337 metres^3/m/year in the 2001 to 2009 period, and are now 6,603 metres^3/m/year in the 2009 to 2017 period. The area closest to the foreshore road (in the Southern section of the bay) has been experiencing an annual loss of 2991 metres^3 over the period 2009 to 2017 and the erosion scarp crest will reach the road verge in ~2024 (i.e. in around 5-6 years). The dune in the middle of the embayment is eroding at ~ 15.6 metres^3/m/year and will be completely eroded away by ~ 2048, if the current 2009 to 2017 erosion rate continues.

Four management options and three recommendations are presented.

Management options:

(i) Brush the upper slopes of the scarp adjacent to the section of the coast road closest to the beach. Place some signage to discourage human activities on the dunes in this vicinity. Eventually, should continued erosion take place, close the section of road most threatened, at, or before 2024.

(ii) Apart from (i) above, do nothing until the coast road fronting the Pool of Siloam is threatened and then decide to either let nature take its course.

(iii) Or, once the dune is largely gone, armour the western margin of the road. Current approximate costs for a seawall are around $2500 - $5000 per linear metre. Total costs could be approximately $650,000 to 1,300,000 to fully protect the Pool from inundation.

(iv) Nourish the two topographic lows in the dune system, the gully and the blowout, to reduce the possibility of wave inundation and overwash in these areas.

Note that if a series of large storms occur in the 2018 winter or next 2-4 years, action will likely need to be taken to close the road at the section closest to the coast road before 2024, and the gully and blowout areas will need to be closely monitored.

Recommendations:

(i) Consider improving and relocating the beach access tracks at both ends of the embayment.

(ii) Maintain the causeway connecting Post Office Rock/Point William to the shore. Ensure the rock height is maintained and ensure that any threat of bypassing is addressed.

(iii) Invest in a UAV/drone such a Phantom 4 Professional and software such as PIX4D to process the images as this device provides a cheap effective method of regularly monitoring the site (and any other site) and producing high resolution aerial imagery.

Introduction

The following report briefly outlines the history of erosion and change at Salmon Hole Beach (also colloquially known as Post Office Rock Beach), provides an updated review of the topographic survey data for the area, describes historical and recent erosion rates, and indicates possible management scenarios for the beach-dune system.

A Brief History of Erosion and Evolution of the Surfzone-Beach-Dune System

1946 to 2016 Overview

In 1946, the earliest photograph available of the region, Salmon Hole Beach which lies to the east of Post Office Rock, and between Point William in the north and Snapper Point in the south, was almost attached to the eastern margin of the aeolianite reef which extends from point to point (Figure 1, yellow arrow). By 2016, the shoreline had retreated westwards and the aeolianite reef was located a significant distance westwards of the shoreline (Figure 1, right side, arrow).

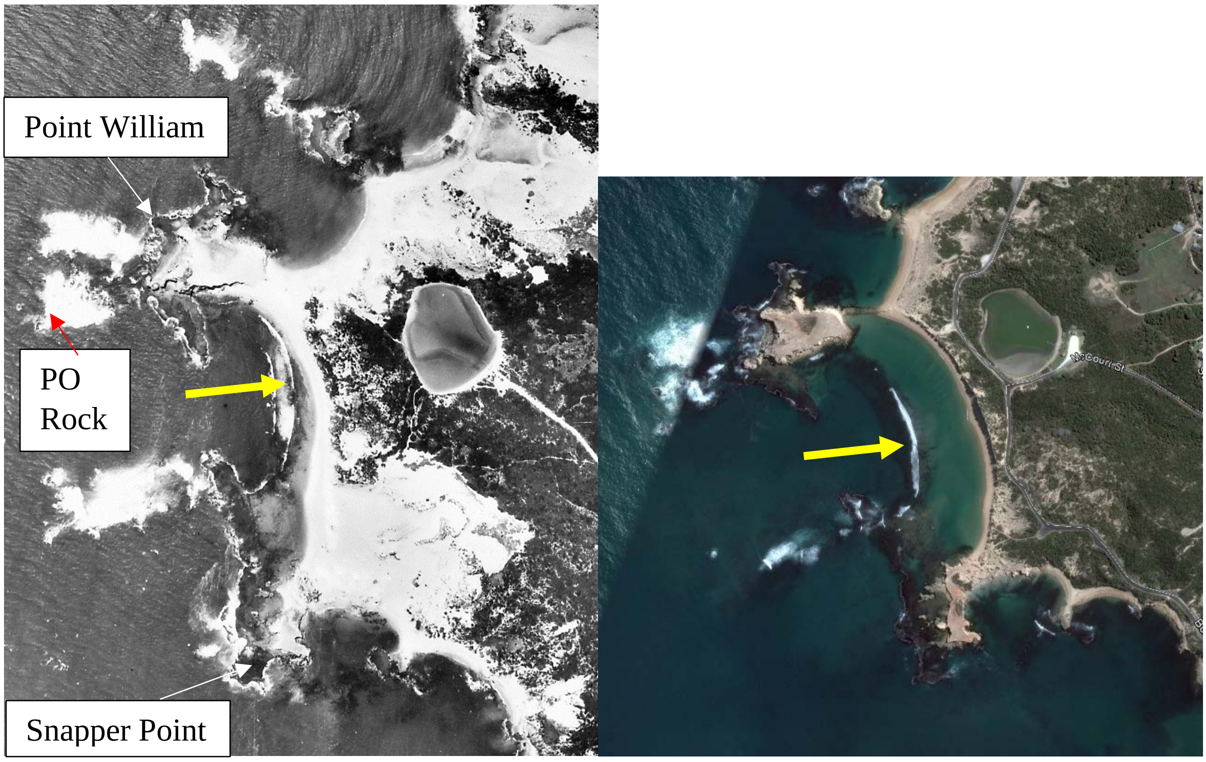

Figure 1: The Post Office Rock region, February, 1946 (left) and 19/4/2016 (right). Salmon Hole Beach lies between Point William and Snapper Point. The dune systems comprised vegetated and active transgressive dunefields in 1946 which by the late 1970's were largely stable and well vegetated. Note that the beach was attached to the reef (yellow arrow) in 1946, and was ~135m eastwards by 2016. Note the distance from the beach to The Pool of Siloam in 1946 versus 2016.

The shoreline retreated ~120 to 135 metres between 1946 and 2016. This is a mean maximum rate of shoreline retreat of ~1.93 metres per year. However, this underestimates the actual rate of shoreline retreat since the shoreline appears to have only started retreating in the post-1975 period.

1975 to 2018

The beach-dune system at Salmon Holes Beach began eroding sometime after 1975 according to Fotheringham (2009). By 1997, the tombolo or strip of sand joining the beach to Point William had decreased in width and the beach had retreated ~50 m in the vicinity of Point William/PO Rock and ~10 m in the vicinity of Snapper Point (Fotheringham, 2009). If the erosion started around 1975, then the mean rate of retreat for the Point William end of the beach was in the order of 2.27 m/year in the period 1975 to 1997. This may be a minimum estimated rate since it is unsure exactly when the erosion began in earnest post-1975.

In the period between 1997 and 2001, a channel was cut through the tombolo, presumably in a large, single storm event, or series of events. Erosion of the beach then appears to have accelerated, with a significant transport of sediment through the tombolo breach to the next beach to the north. Fotheringham (2009) estimates the shoreline at the Point William/PO Rock end eroded a further 50 m between 1997 and 2004, an erosion rate of ~7.14 m/year.

A series of 15 topographic survey profile lines were established along the dune-beach system in 2001 by DEWNR in order to monitor the erosion rates and changes. The profiles were surveyed from the centre point of the road across the dunes to the water edge. They are spaced approximately 30 metres apart (Figure 2).

An artificial tombolo or groyne was constructed in December, 2003 joining the northern end of the beach to Point William. This was overtopped by storm waves in April 2006, and the groyne was rebuilt with larger rock materials in February, 2007 (Fotheringham, 2009). In April, 2013 more rock was added to the causeway to make it wider and to raise the elevation to 0.5 m AHD. In June, 2013 the causeway was extended to prevent bypassing. The extension consisted of rock wrapped in geotextile which was placed in a trench and buried. Note that observations in 2017 during a moderate storm and at high tide showed that waves and swash were nearly crossing the sandy beach connecting the eastern end of the groyne structure. It is therefore possible that the groyne could be cut off by waves crossing and eroding the sandy strip which links the beach to the groyne as erosion continues.

In the period 2001 to 2008, average erosion rates for all 16 profiles extending along the beach-dune system ranged from 2.89 (2007-2008) to 5.04 (2002-2003) m/year. Erosion rates declined post-2003 after the groyne was constructed, and generally continued to decline to November, 2008 (Fotheringham, 2009).

In the period between 13/11/2003 and 19/4/2016 (12 years, 3 months) a comparison of satellite imagery available in Google Earth indicates that in the middle of the bay, the dune scarp crest retreated ~ 19 metres and the dune scarp base ~ 28 metres, giving a rate of shoreline retreat of ~ 0.19 metres per month or roughly 2.28 metres per year. This is still a reasonably high rate of erosion relative to typical erosion rates of beaches around the world.

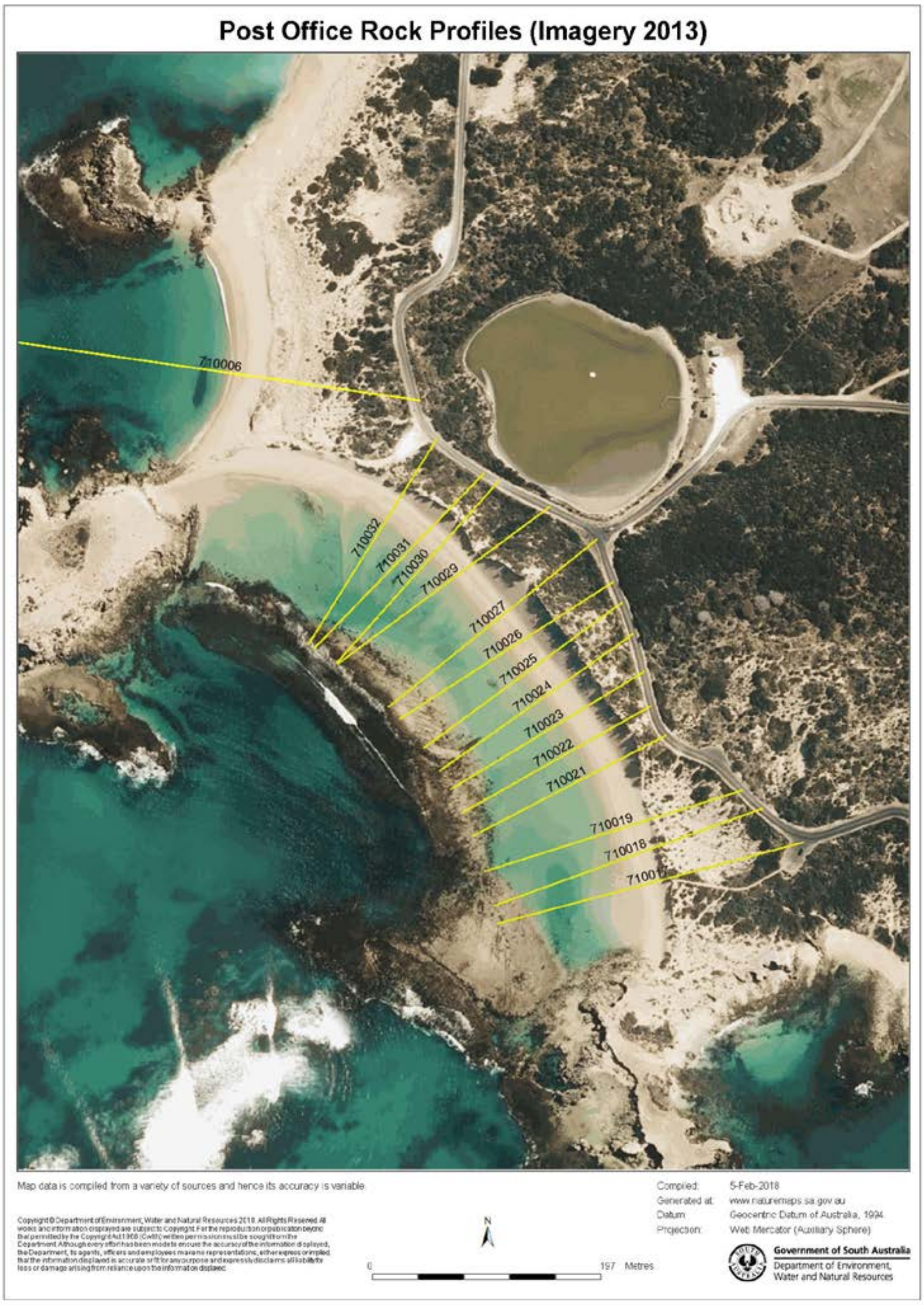

Figure 2: Profile locations at Post Office Rock. Each profile has an identification number.

Surfzone-Nearshore Processes

The surfzone-nearshore adjacent to Salmon Hole Beach is operating as a reef enclosed ‘lagoon’. During high wave events, it is likely that there is considerable set-up (barometric forced increase in water elevation) of water levels inside the ‘lagoon’ due to the presence of the reef. Fotheringham (2009) indicated water levels may be increased by up to a metre. Even without this set-up of water levels, high waves traversing the reef act to force water movement from south to north along the ‘lagoon’. These currents were the principal driver transporting sediment out of the embayment once the tombolo was breached. It has been estimated that ~72,000 m^3 of sand was transported out of the embayment between 2001 and 2006.

Even after the tombolo was recreated by groyne construction, these currents are also operating at times to create a suite of transverse dunes. The subaqueous transverse dunes are ~ 50 m in length along-crest and spaced ~15 m apart (Figure 3). They are quite unusual in surfzones as most bars are arranged in various morphologies parallel to the shoreline (Wright and Short, 1984). Their presence indicates very strong currents at times trending alongshore from SSE in an arc to NNW, and capable of transporting significant amounts of sediment.

Figure 3: Google Earth image of the reef, surfzone 'lagoon', a suite of subaqueous transverse dunes in the lagoon indicated by the yellow arrow, and the reef/bedrock controlled rip channel (red arrow) at the northern end of the lagoon.

Figure 4: View of the reef and the reef/bedrock controlled rip channel (red arrow) at the northern end of the 'lagoon' during a low tide event, February, 2018.

The other major driver of sediment and water movement is a permanent rock arrested rip channel located at the northern end of the embayment adjacent to Point William/PO Rock. It is likely that sediment has always, and is still being transported offshore through this rip channel during moderate to strong wave events (Figures 3 and 4). The rip generating this channel is a hazard to swimmers and warning signs are recommended.

Rates of Erosion and Beach-Dune Change to 2018

Methodology

The profiles have been surveyed by DEWNR using an RTK GPS system. The measurement accuracy of the profiles both vertically and horizontally is a few mm. In general, erosion scarps were only measured top (crest) and bottom (base) due their steepness, and not on the slope. Some profiles have been measured every year while others have not. Elevations are in metres, Australian Height Datum (AHD).

Two profile analysis programmes have been used. CalcVol is a programme that calculates the volume above a specified elevation. CalChainage is a programme that calculates the distance a specified elevation is from the profile starting point.

2 metres AHD was selected for the base level of volume and erosion analysis. This height as indicated in Figure 5, profile 710027, approximates the dune toe/top of the backshore at Salmon Hole/Post Office Rock Beach. Volumes in this report are above this height.

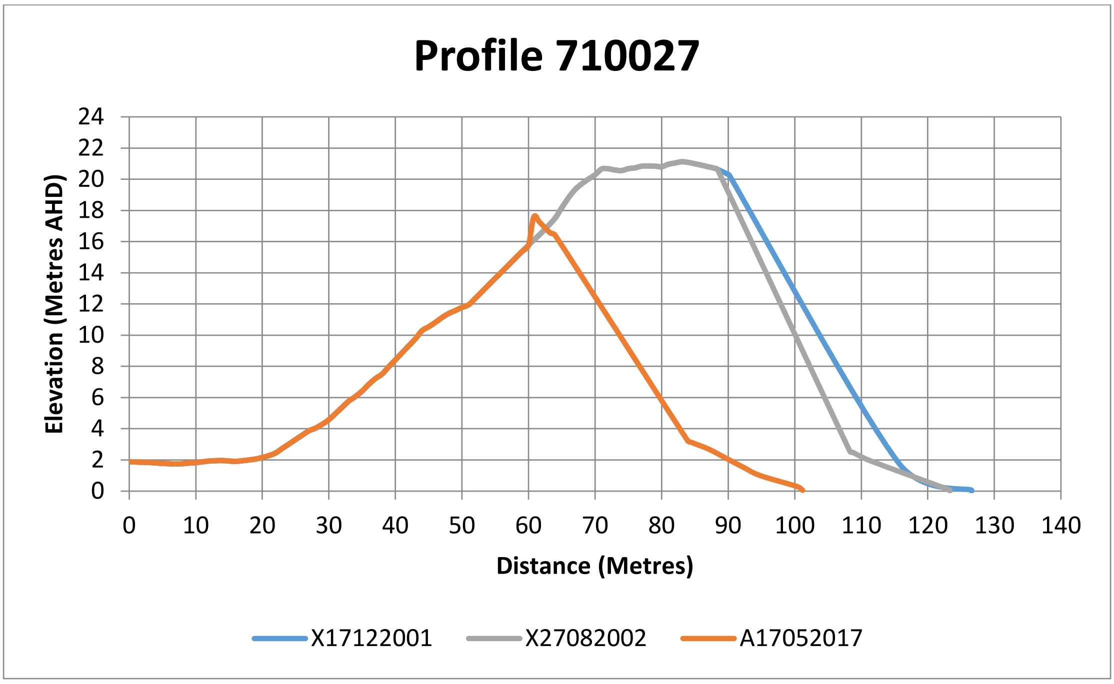

Figure 5: Plot of profile 710027 near the middle of the embayment showing changes between 2001 (blue), 2002 (grey), and 2017 (orange).

Total volume loss was calculated using a method previously used on the Adelaide beaches. Each profile represents the distance halfway to the profile on either side. The profile volume change is then multiplied by this distance to provide a volume. These are added to provide an overall volume for the Salmon Hole beach compartment. Distances were measured using the measuring tool on NatureMaps as shown in Figure 6.

Figure 6. Distances measured along the beach to each profile line and used to calculate overall volumes for selected years.

Overall, volumes were calculated for 2001, 2009 and 2017. All profiles were surveyed in these years.

Three profiles have been selected for display of which two are critical for this study. Profile 70021 is located in the southern end of the bay and crosses the area closest to the coast road;

that is, the most vulnerable section of infrastructure. Profile 70027 is located in the middle of the bay and therefore provides an indication of the average retreat of the bay.

Results

Volume analyses

Table 1 shows the volumetric analyses. Columns B, C and D show profile volumes in 2001, 2009 and 2017. Profile volume loss between 2001 and 2009 and 2009 and 2017 is shown in columns E, F and G. Profile segment distances are shown in column H. Profile segment volumes are then shown for the comparison periods in columns I, J and K. The yellow highlighted rows and column L show profiles along the section of coast closest to the foreshore road (located landwards of profile 21 on Figure 2).

Total volume loss over the 16 year period is 175,520 metres^3. Average annual loss was 10,970 metres^3. During the period 2001 to 2009 the annual loss was 15,337 metres^3. Annual loss was significantly lower for the period 2009 to 2017 and was 6,603 metres^3 indicating the rate of erosion is decreasing since 2009. The segment closest to the foreshore/coast road is highlighted yellow and has been experiencing an annual loss of 2,991 metres^3 over the period 2009 to 2017 (Figure 7).

Figure 7. Google Earth images from 2003, 2010 and 2014 (left to right) illustrating the rate of erosion. The yellow pin located several metres landwards of the scarp crest in the November, 2003 image is located at the scarp crest by 2010, and half way down the scarp by 2014.

A	B	C	D	E	F	G	H	I	J	K
Profile ID	Profile volume 2001	Profile volume 2009	Profile volume 2017	Loss 2001-09	Loss 2009-17	Total Loss 2001-17	Profile segment (m)	Profile segment volume loss 2001 -17	Profile segment volume 2001-09	Profile segment volume 2009-17
710017	809	702	668	107	34	141	86	12,126	9,202	2,924
710018	805	708	677	97	31	128	25.5	3,264	2,474	791
710019	855	768	742	87	26	113	40	4,520	3,480	1,040
710021	829	509	350	320	159	479	41.5	19,879	13,280	6,599
710022	729	475	345	254	130	384	28	10,752	7,112	3,640
710023	801	493	344	308	149	457	29.5	13,482	9,086	4,396
710024	885	579	411	306	168	474	27	12,798	8,262	4,536
710025	1,128	789	620	339	169	508	24.5	12,446	8,306	4,141
710026	999	669	504	330	165	495	27	13,365	8,910	4,455
710027	1,028	675	481	353	194	547	42.5	23,248	15,003	8,245
710029	422	259	207	163	52	215	42.5	9,138	6,928	2,210
710030	473	286	212	187	74	261	23.5	6,134	4,395	1,739
710031	500	271	195	229	76	305	28	8,540	6,412	2,128
710032	375	249	211	126	38	164	157.5	25,830	19,845	5,985
Total loss								175,520	122,693	52,827
Annual Loss								10,970	15,337	6,603

Table 1. Volume analysis. The base datum for volume calculations was 2 m AHD. The yellow highlighted portion indicates the profiles located closest to the most vulnerable section of the coast road. Columns J and K show total loss and annual loss for the 2001-09 and 2009-17 periods.

Erosion analysis

Table 2 details the erosion data. Columns B, C and D show the dune toe position (metres) in relation to the profile starting point for 2001, 2009, and 2017. Columns E, F and G show the erosion for each of the comparison periods. The average erosion was 20 metres for the period 2001 to 2009. Average erosion for the period 2009 to 2017 was significantly less at 9 metres (~1.1 m/year). Erosion rates are much more uniform between the profiles in 2009 to 2017 compared to the period 2001- 2009. This is shown in Figure 8.

A	B	C	D	E	F	G
Profile	2001 (m)	2009 (m)	2017 (m)	01-09 (m)	09-17 (m)	01-17 (m)
710017	151	130	123	21	7	28
710018	127	106	99	21	7	28
710019	116	95	86	21	9	30
710021	76	54	42	22	12	34
710022	78	51	42	27	9	36
710023	88	63	53	25	10	35
710024	98	74	64	24	10	34
710025	105	82	73	23	9	32
710026	107	88	79	19	9	28
710027	115	98	90	17	8	25
710029	100	86	77	14	9	23
710030	82	69	60	13	9	22
710031	79	66	57	13	9	22
710032	78	63	57	15	6	21
Average				20	9	28

Table 2. Distance of dune toe (at 2 m AHD) from profile starting position, and erosion extent for the comparison periods of 2001 to 2009, 2009 to 2017, and 2001 to 2017.

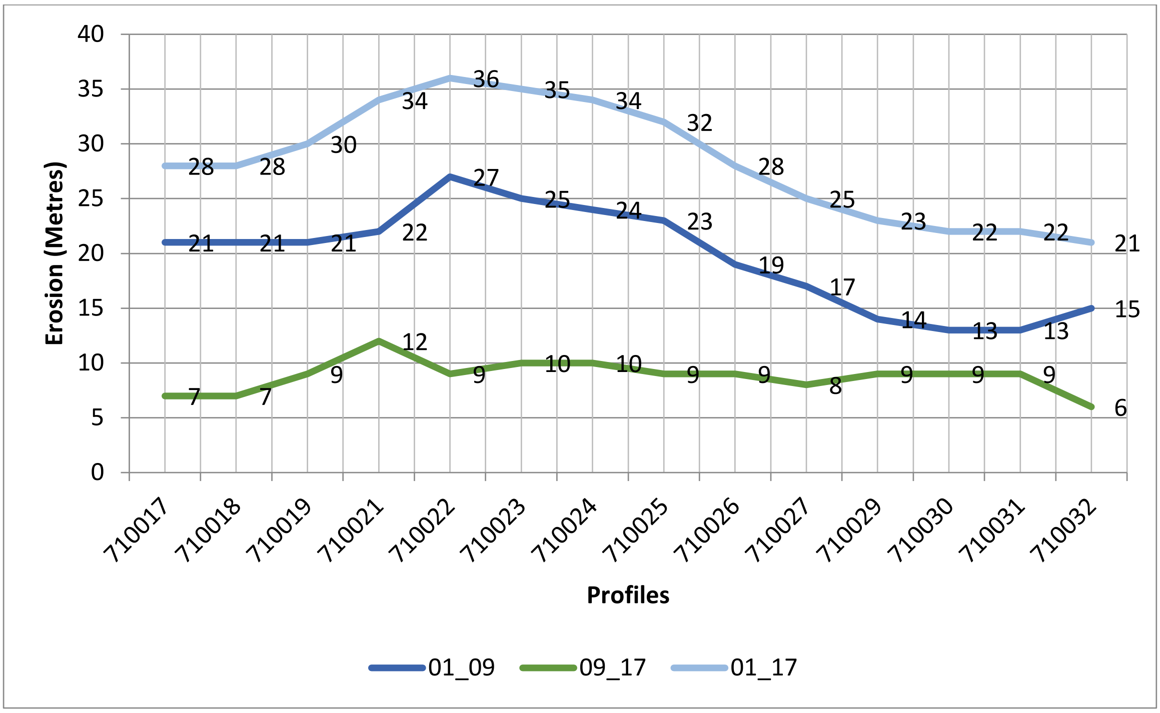

Figure 8. Graph showing erosion rates for profiles 17 (southern end) to 33 (northern end) for the periods 2001-2009, 2009-2017, and 2001-2017.

Selected Profiles

Profile 710021 is located in front of the coast road that is closest to the beach and was surveyed every year. Profile 710027 is located in the middle of the beach embayment and was also surveyed each year. Profile 710006 is located on the north side of the tombolo/groyne (see Figure 2 for locations).

Tables 3, 4 and 5 show the erosion setback and volume losses for each of the profiles from 2001 to 2017. Figures 9, 10 and 11 show a graph of cumulative erosion at each of the profiles.

A Year	B Distance from Start Metres	C Erosion Distance Metres	D Cumulative Metres	E Volume Metres³	F Volume loss/gain Metres³	G Cumulative Metres³
2001	76	0	0	884		
2002	71	-5	-5	818	-66	-66
2003	69	-2	-7	710	-108	-174
2004	65	-4	-11	652	-58	-232
2005	62	-3	-14	640	-12	-244
2006	62	0	-14	601	-39	-283
2007	55	-7	-21	562	-39	-322
2008	57	2	-19	562	0	-322
2009	51	-6	-25	509	-53	-375
2010	50	-1	-26	482	-27	-402
2011	48	-2	-28	471	-11	-413
2012	47	-1	-29	461	-10	-423
2013	48	1	-28	435	-26	-449
2014	47	-1	-29	409	-26	-475
2015	44	-3	-32	381	-28	-503
2016	45	1	-31	373	-8	-511
2017	42	-3	-34	350	-23	-534

Table 3. Erosion and volume losses, profile 710021 (adjacent to the closest portion of the coast road).

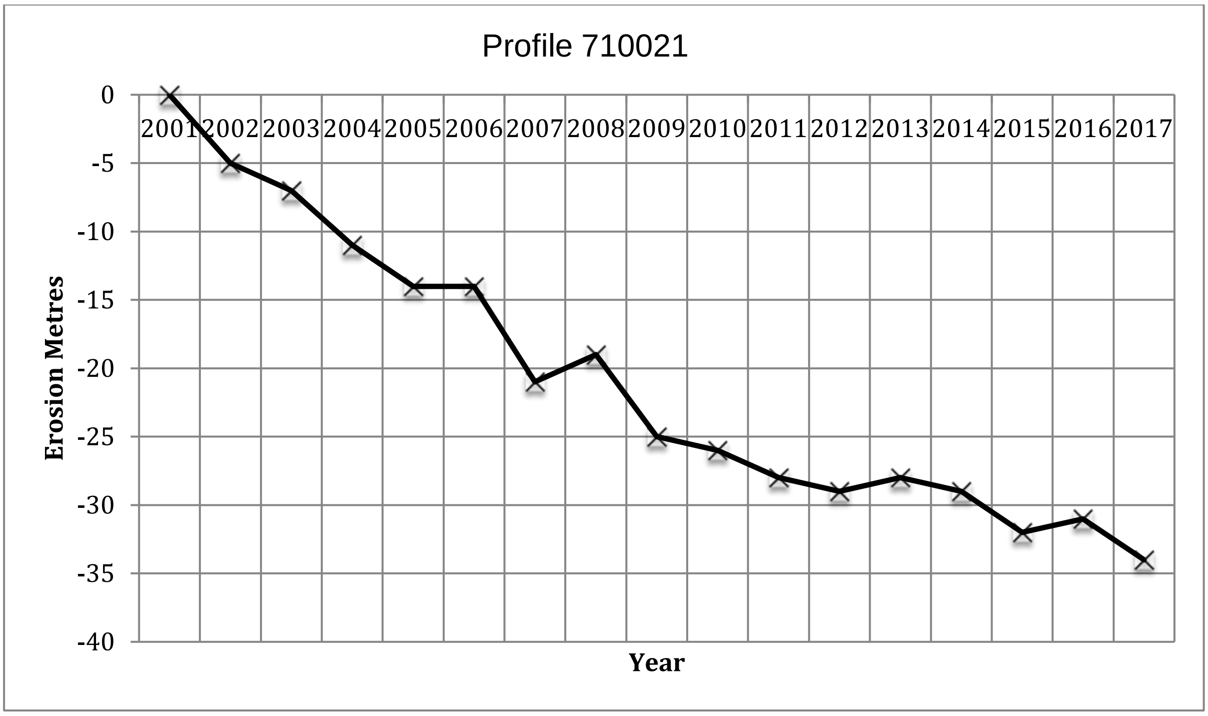

Figure 9. Cumulative erosion for Profile 710021, 2001 to 2017. The rate of erosion is declining since 2009.

A Year	B Distance from Start Metres	C Erosion Distance Metres	D Cumulative Metres	E Volume Metres^3	F Volume loss/gain Metres^3	G Cumulative Metres^3
2001	115.37			1028		
2002	111.13	-4.24	-4.24	961	-67	-67
2003	111.06	-0.07	-4.31	868	-93	-160
2004	107.17	-3.89	-8.2	835	-33	-193
2005	105.8	-1.37	-9.57	854	19	-174
2006	101.82	-3.98	-13.55	793	-61	-235
2007	103.22	1.4	-12.15	735	-58	-293
2008	99.9	-3.32	-15.47	711	-24	-317
2009	98.36	-1.54	-17.01	675	-36	-353
2010	96.59	-1.77	-18.78	628	-47	-400
2011	96.74	0.15	-18.63	599	-29	-429
2012	97.6	0.86	-17.77	592	-7	-436
2013	93.62	-3.98	-21.75	576	-16	-452
2014	91.08	-2.54	-24.29	530	-46	-498
2015	90.17	-0.91	-25.2	529	-1	-499
2016	91.25	1.08	-24.12	527	-2	-501
2017	90.2	-1.05	-25.17	481	-46	-547

Table 4. Erosion and volume losses, profile 710027, in the middle of the embayment.

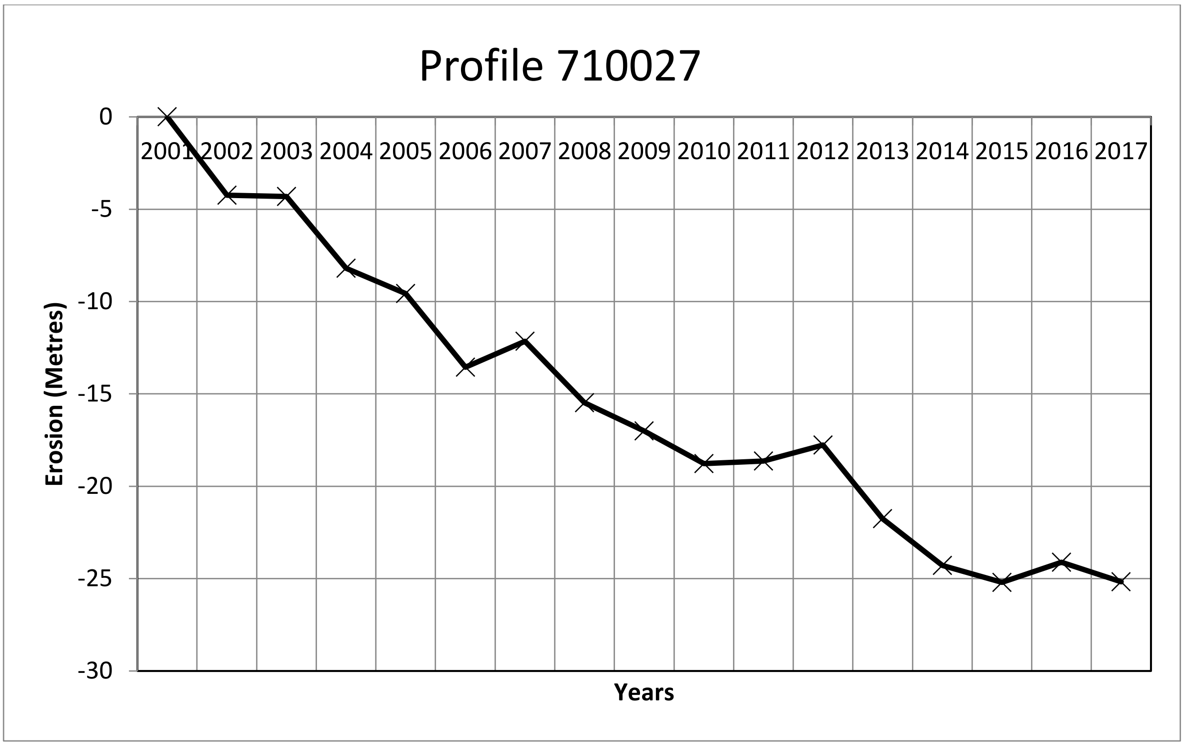

Figure 10. Cumulative erosion on Profile 710027, 2001 to 2017. The rate of erosion has slowed since 2009.

A Year	B Distance from Start	C Erosion Distance	D Cumulative	E Volume	F Volume loss/gain	G Cumulative
2002	152	0	0	419		0
2003	156	4	4	427	8	8
2004	150	-6	-2	432	5	13
2005	144	-6	-8	434	2	15
2006	145	1	-7	435	1	16
2007	146	1	-6	440	5	21
2008	144	-2	-8	448	8	29
2009	140	-4	-12	455	7	36
2010	141	1	-11	454	-1	35
2011	140	-1	-12	453	-1	34
2012	140	0	-12	454	1	35
2013	139	-1	-13	452	-2	33
2014	137	-2	-15	447	-5	28
2015	136	-1	-16	441	-6	22
2016	134	-2	-18	436	-5	17

Table 5. Erosion and volume losses, profile 710006, north of the embayment and groyne.

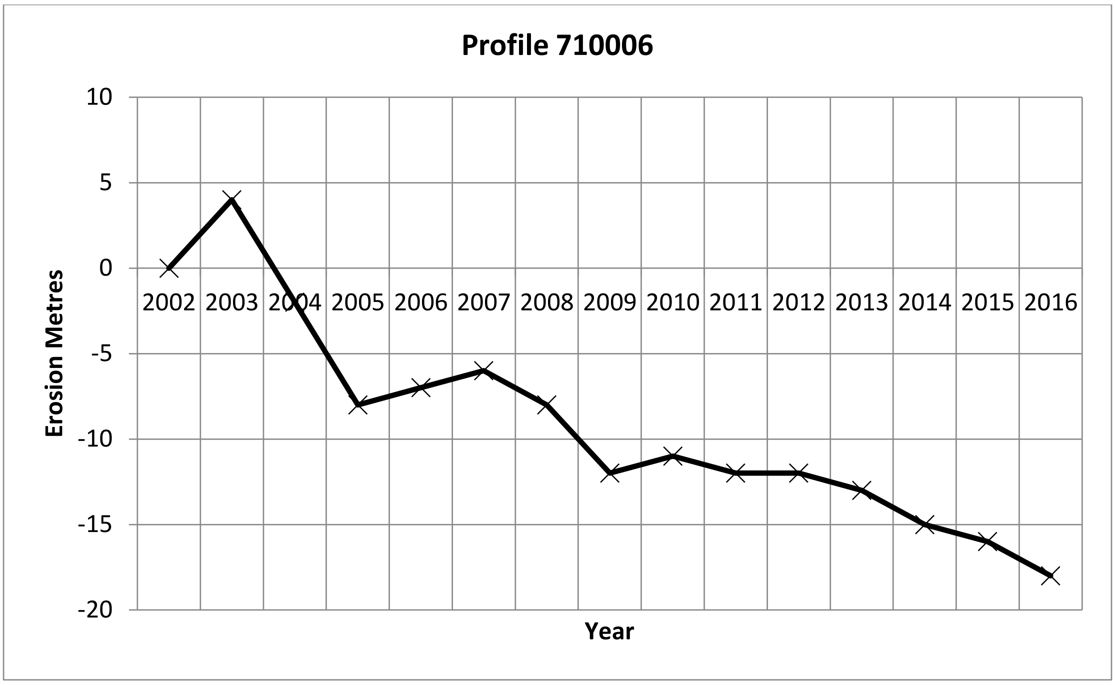

Figure 11. Cumulative erosion Profile 710006, 2002 to 2016.

Vulnerability of the Coast Road

The road is most vulnerable to erosion at profile 710021 near the southern end of the embayment (Figure 6). A plot of the 2017 profile is shown in Figure 12. This survey shows that the top of the erosion scarp was 19.46 metres from the centreline of the road. The profile, which starts at the centreline, extends across 4.12 m of bitumen, and the verge extends to 6.36 metres distance. The scarp toe is at 37.71 metres.

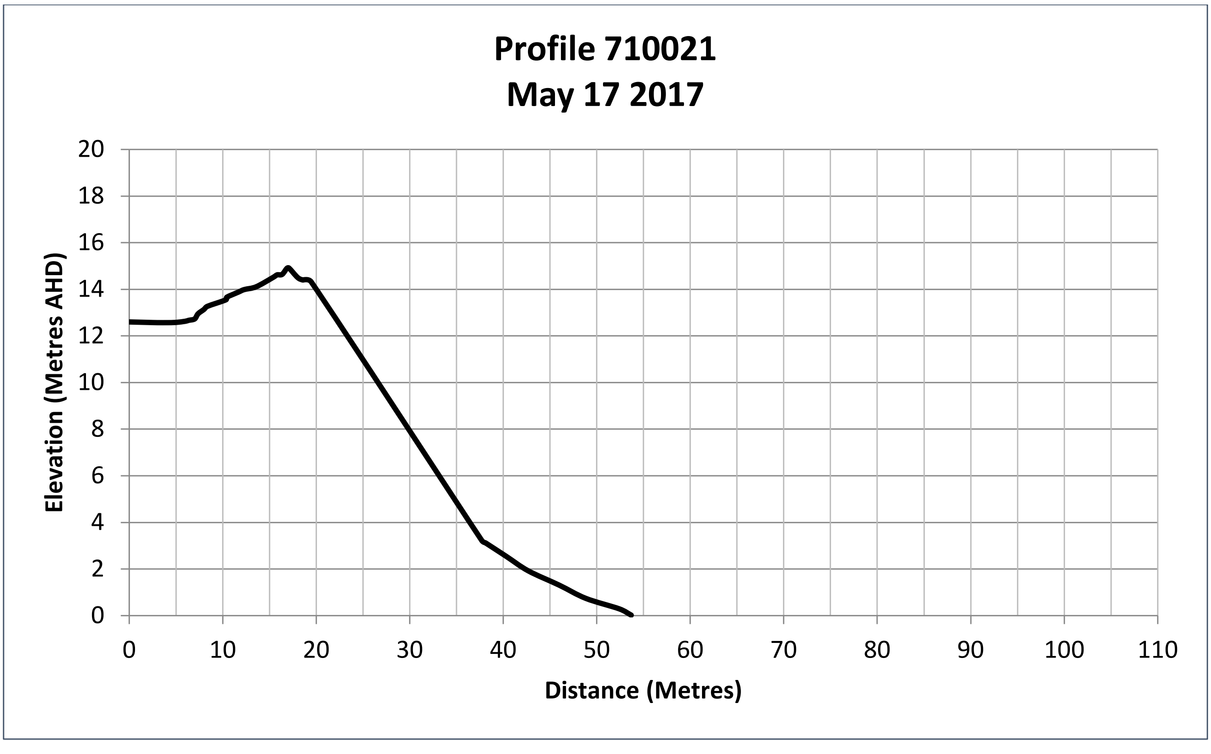

Figure 12: Profile 710021. The middle of the coast road is located at zero metres in this figure.

The average annual volumetric loss estimated for Profile 710021 for the 2009 -17 period is 22.87 m^3/m. The current dune volume (above 2 m AHD) to the middle of the road is ~ 171.5 m^3/m. At the current rate of erosion the top of the erosion scarp will be close to the road verge (~7 m distance from zero in Figure 12) in 7.5 years (from May, 2017) or by mid-2024.

Profile 710027 is located in the middle of the embayment seawards of the middle of the Pool of Siloam (Figure 6 and 13).

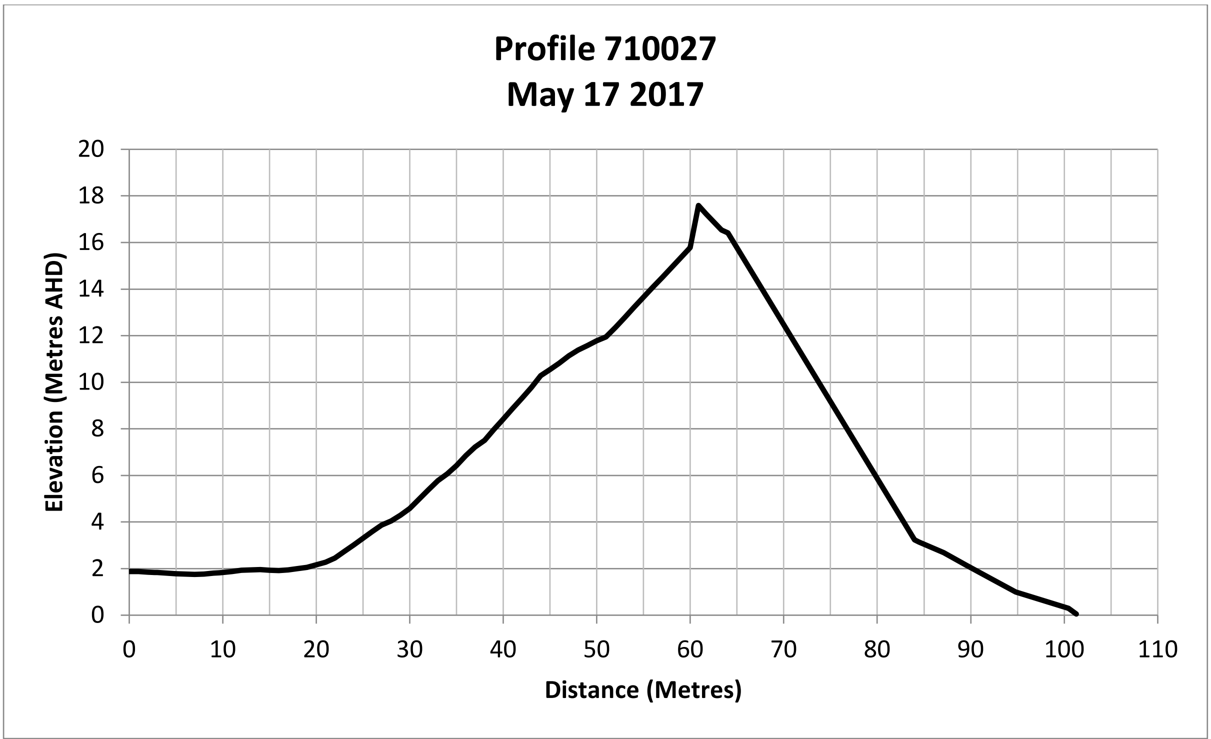

Figure 13: Profile 710027 located in the middle of the embayment.

The average annual volumetric loss for this portion of the embayment at profile 710027 is 15.62 m^3/m/year for the 2009 to 2017 period. The current dune volume (above 2 m AHD) is ~ 474 m^3/m. At the current erosion rate, the dune will be removed and the 2 m elevation point 20 metres seaward of the road will be reached in approximately 30 years (from May, 2017) or by 2048.

Management Options

Option 1: Manage the aeolian sand transport onto the road; Otherwise Do Little and Observe

While the degree of erosion varies from year to year due to the impacts of storms in some years, the erosion rate along the embayment is generally slowing down as the Tables and Figures above indicate. The average erosion rate has decreased in the 2009 to 2017 period compared to the 2001 to 2009 period (Figure 8). During the period 2001 to 2009 the annual loss was 15,337 $metres^3$, while for the period 2009 to 2017 it was 6603 $metres^3$. This is obviously still a decent rate of erosion, but since the rate is decreasing, an option is to only deal with the sand transport issue on the dunes adjacent to the road in the area located around profiles 700021 and 22. In this location (Figure 14), sand is transported off the seaward erosional dune scarp and deposited on the lee slope, road verge and road depending on the wind velocity at the time. The immediate management action here is to stabilize the eroding surface to the degree possible by laying overlapping brush (typically *Acacia* cuttings or other native plant cuttings) across the surface.

As the dune continues to retreat, this brushing may have to be repeated to reduce sand transport landwards. Once (or if) the dune scarp is relatively close to the road verge, the road will have to be closed. As noted above, the dune scarp will be near the road verge by 2024. The stability of the dune will be need to be assessed before this time to see if it is stable enough to adequately support the road.

Other than the brushing/local dune management/possible future local road closure, the option is to simply continue topographic surveys and observe dune and beach changes. If this option is taken, the Council should liaise with the Coastal Management Branch (CMB) to ensure the regular profile monitoring continues. The council should also discuss with CMB the possibility of increasing the number of topographic surveys conducted per year at least on one to three of the existing survey lines in order to better monitor changes, especially after significant storms. Regular UAV drone flights would also accomplish this task in a more geographically expansive way.

Figure 14. The currently most vulnerable section of the coast road (arrowed). The scarp crest is only ~14 m from the edge of the road. Brushing of the upper scarp will reduce sand transport onto the road. However, if dune erosion continues, it is likely that in the future the road will need to be closed north of the parking area (where the vehicle is parked in the photograph).

Option 2: Do Nothing

Apart from the brushing option noted above, and eventual closure of the road nearest the dune scarp (around profile 21), an option is to allow natural processes to occur, and if erosion continues, the Pool of Siloam will eventually likely form the new coastal embayment. However the implications of a sea breach of the lake should be investigated.

Option 3: Armour the western margin of the coast road if the dune is removed.

If erosion continues, and the coast road fronting the Pool of Siloam is threatened, an option could be to armour the seaward side of the road to prevent further erosion and loss of the road, and inundation of the Pool and surrounding area.

Past estimates of when the dune would be largely gone and the road and Pool inundated were calculated in Fotheringham's (2009) report. If the former erosion rate was sustained this would occur by 2028 at profile 710032 (Scenario 2 of Fotheringham, 2009, where the groyne remains intact). Since that 2009 report was finished, erosion rates have decreased so it is likely, based on 2009-2017 average annual volumetric losses of 15.62 m^3/m/year for the 2009 to 2017 period, the dune will be removed and the 2 m elevation point 20 metres seaward of the road will be reached in ~30 years, that is, by 2048. This estimate, however, does not take into account two possibilities: (i) that the erosion may eventually cease before this time (it has slowed in recent times and this trend may continue); or, (ii) that a series of large storms occur within a short period of a few months, or a year or two and the dune erosion is such that the dune system is so significantly eroded or eradicated that inundation into the Pool and environs occurs.

The cost of building a seawall along a distance of approximately 260m will be significant and range from $650,000 to $1.3 million.

An alternative scenario is that local overwash during a storm occurs at the two low points in the present dune, and the coast road, Pool of Siloam and adjacent area is more locally inundated or flooded. Options for this scenario are detailed below.

Option 4: Nourish the two topographic low points in the dune system

There are two topographic lows in the current dune system (Figure 15). One, here termed the gully, is located immediately adjacent to (just south) of the carpark situated at the northern end of the embayment. Two, there is a blowout in the central-northern portion of the dune system opposite the Pool of Siloam (Figure 15).

The greatest immediate threat to inundation and erosion of the coast road and the Pool of Siloam and environs is if either or both of these are cut through, inundated or overtopped by storm waves. Such an event could produce a significant overwash channel down through these lows, across the eastern portion of the dune system and onto the road and into the Pool of Siloam. This could cut the dune into two or potentially three segments depending if one or both occurred respectively.

Option 4 involves adding sand to both of these to reduce this possibility and extend the time within which no flooding of the eastern dunes, road and Pool occurs.

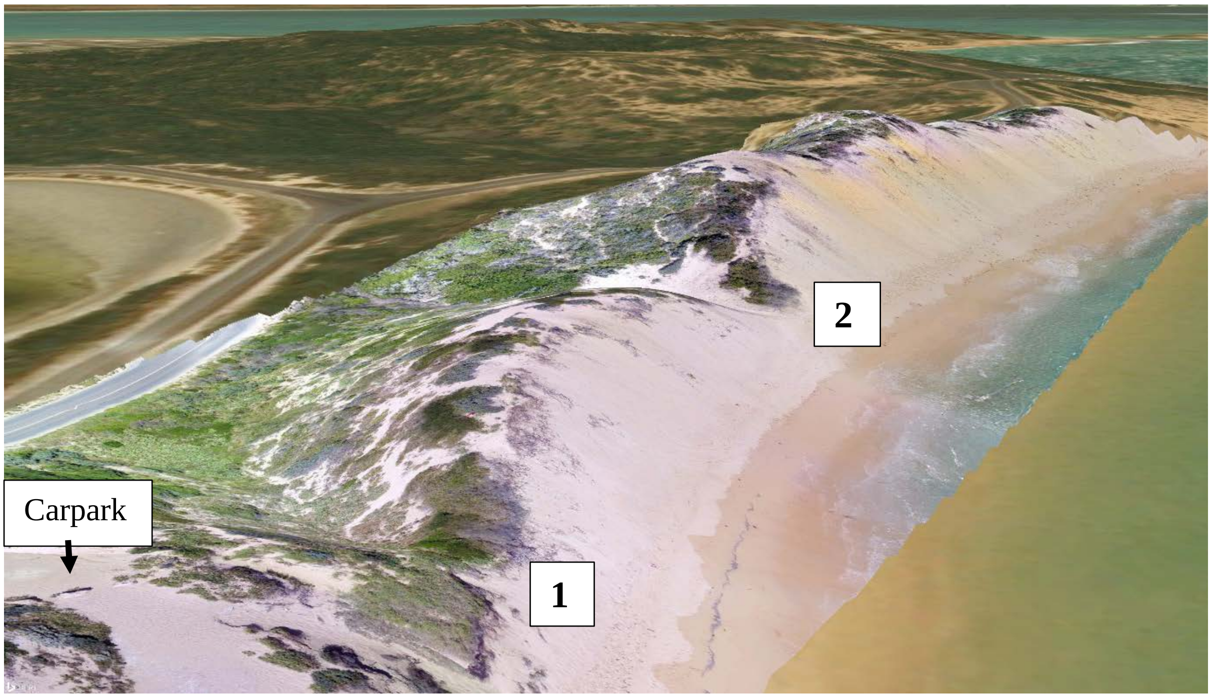

Figure 15: DEM produced from a February, 2018 UAV drone flight and overlaid on a Google Earth image showing the dune system and the two topographic low areas. 1 – Gully; 2 – Blowout.

The Gully

The gully lies ~23 m landwards of the present dune scarp, the crest of which is at an elevation of 7.5 m. Figure 16 illustrates the present topography extending up through the lowest portions of the dune system and gully and over the scarp crest to the beach.

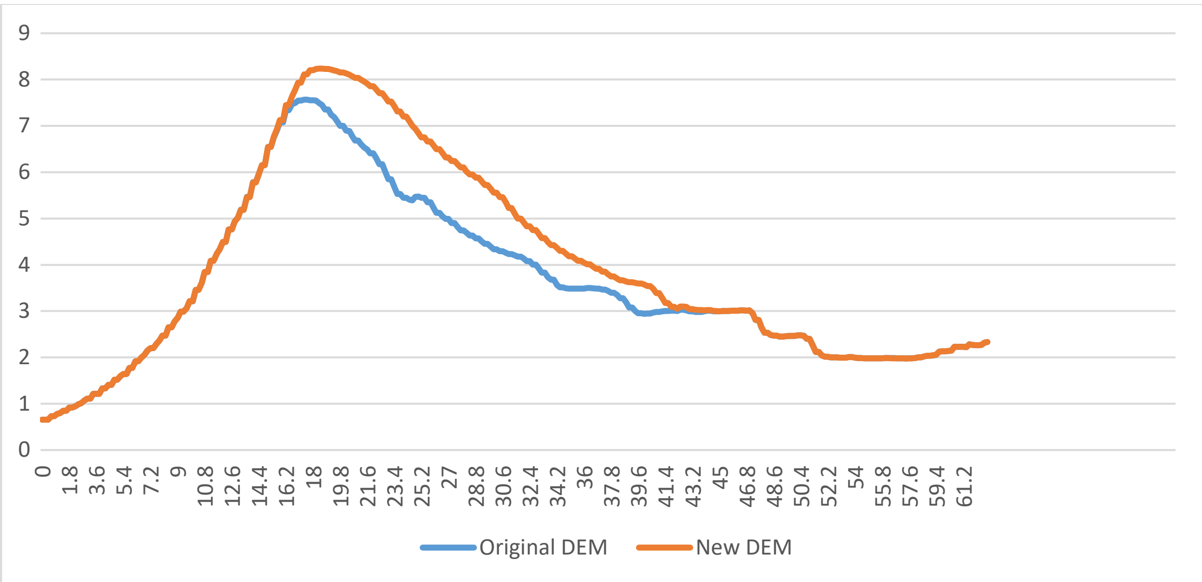

Figure 16: Present topography (blue) of the dune fronting the gully section (at profile 710032) and the nourishment profile (orange).

The current dune profile at the Gully has an approximate volume of 93 m^3/m (above 2 m AHD), and at an estimated rate of erosion of 7.4 m^3 per year the dune will be gone within ~10 years if the current erosion rate continues. Superimposed on the present 2018 topographic profile shown in Figure 16 is a post-nourishment profile. This latter profile is a minimum volume required to raise the crest level and primarily to extend the crest region landwards, thereby reducing the chances of waves eventually breaking through and into the gully. The total estimated volume required to achieve this nourishment is 192m^3. The nourishment profile shown in Figure 16 contains another 21 m^3/m. This extra sediment will only add a little less than an extra 3 years life to the dune. The nourishment profile indicated does not therefore add much life to the dune, but is provided as an indication of how much minimum sediment volume would need to be added *each 3 years* post-2019 to prevent overwash occurring.

Figure 17 illustrates the nourishment sand overlaid on a recent (February, 2018, Digital Elevation Model (DEM) of the dune produced from a UAV drone flight. In the case of the gully, the placement of the sand could be achieved relatively easily with minimal impact by vehicles on the vegetation, by simply tipping sand into the gully from the edge of the carpark margin. Nonetheless, vegetation would be impacted where the nourishment fill is placed and native vegetation impacts will have to be considered.

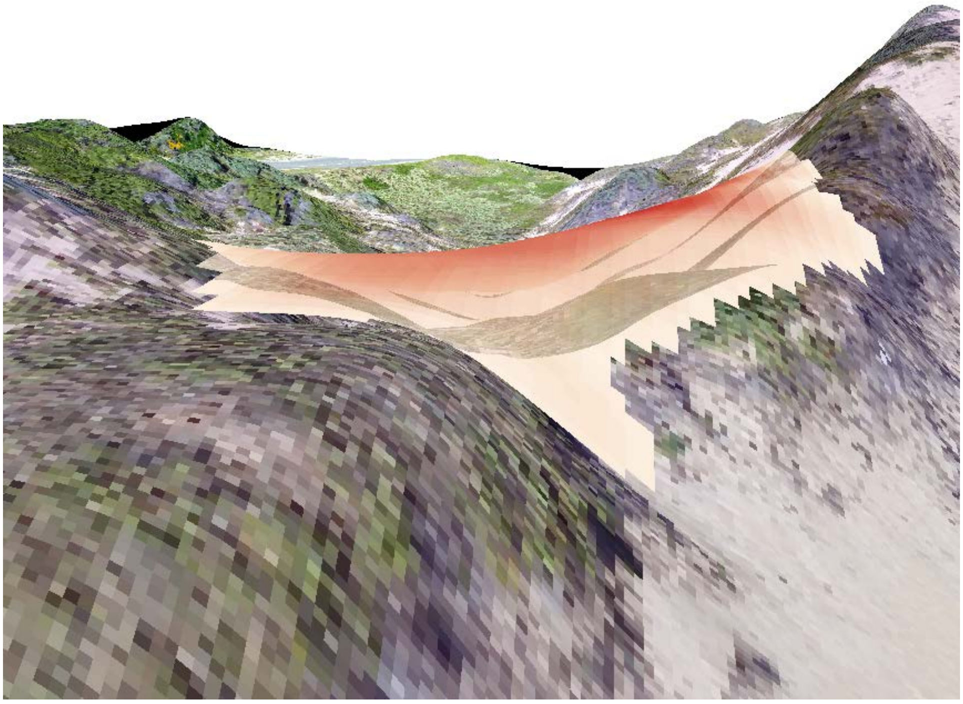

Figure 17: The gully location with nourishment sand overlaid on a February, 2018, Digital Elevation Model of the dune produced from a UAV drone flight.

Blowout

Figure 18 illustrates the blowout and landwards, low elevation, partially tracked strip extending eastwards to the road and Lake. The blowout entrance is currently only 3m above mean sea level.

The blowout comprises a throat (entrance) region (6 to 10m distance landwards in Figure 19), deflation surface (10m to 23m distance in Figure 18), and depositional lobe extending from ~23m to 45m landwards (Figure 19). The throat or entrance region rises to ~3.5 m above AHD, an elevation which could be presently reached by storm waves acting on top of a 1 metre setup in water level at high tide. The profile shown in Figure 19 traverses across the blowout and then across the lowest topography towards the Pool. However, a low swale continues seawards up the side of the depositional lobe. This provides a path of least resistance should waves reach into the blowout and wash down into the low topography.

This profile shown in Figure 19 is therefore the maximum volume present and comprises ~90 m^3/m in its current form (above 2 m AHD). The nourishment volume comprises 83 m^3 and the profile (Figure 19) contains ~11 m^3/m and primarily raises the height of the dune to prevent inundation into the blowout and overwash/inundation down the lower, northern side of the depositional lobe. This is also a minimum nourishment volume, and clearly a much greater volume placed in this location would improve the medium term "stability" of this location.

Figure 18: Aerial photograph of the blowout and environs produced from a UAV drone survey on the 24th January, 2018.

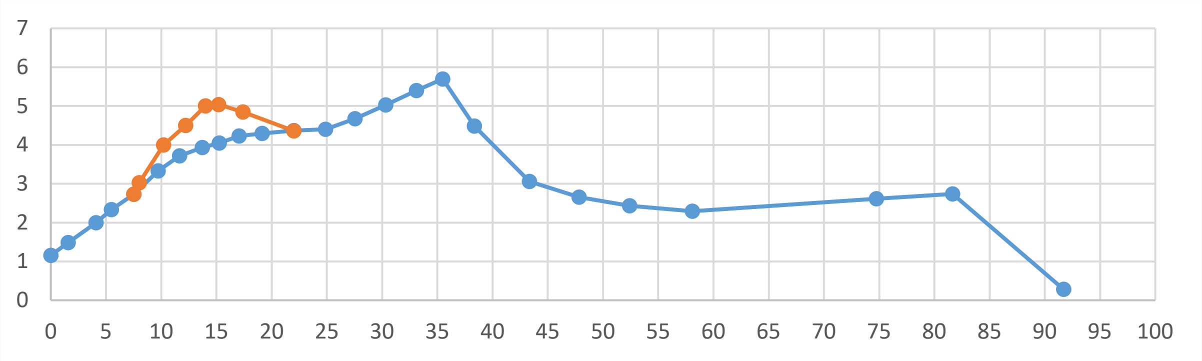

Figure 19: Present blowout profile (blue) and proposed nourishment profile (orange). Currently high tides reach to ~2.5 to 3 m AHD.

Figure 20 illustrates the nourishment sand overlaid on a recent (February, 2018) Digital Elevation Model (DEM) of the dune and blowout produced from a UAV drone flight.

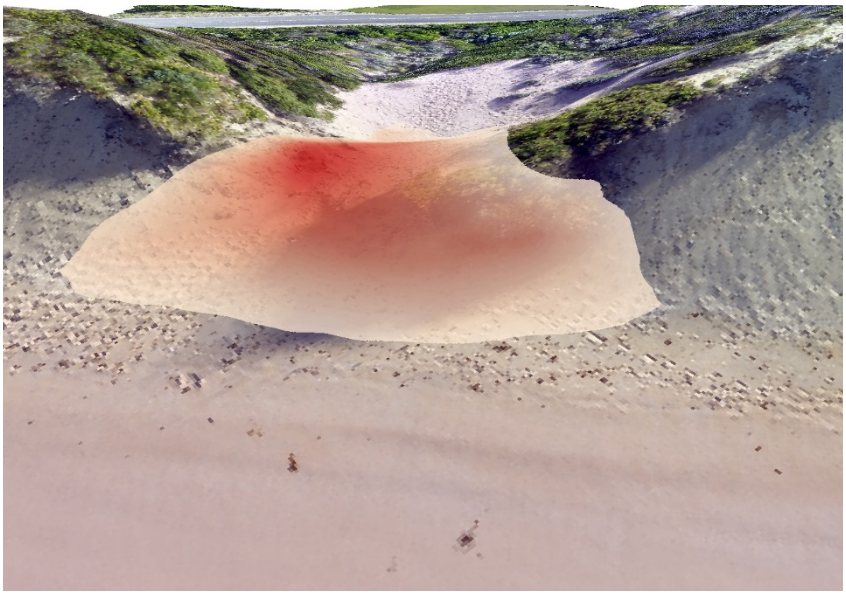

Figure 20: Drone DEM of the blowout with overlaid proposed nourishment sand.

There is a significantly greater difficulty providing nourishment sand to this site. It may be possible at a very low tide and low wave energy day to get a tracked vehicle along the beach and dump sand into the blowout entrance. This option is not without considerable risk. The other option is to create a track across the native vegetation from the coast road to the blowout and then deliver sand to the entrance via that route. This option will have impacts on native vegetation. However, if waves break through into the blowout and then down across the dune system and into the Pool, the native vegetation will be severely impacted and likely killed, so a short term track, later rehabilitated, is likely a lesser impact option.

Beach Access

Beach access will continue to be an issue at this beach as erosion continues. The access at the northern end is now relatively dangerous with a significant cliff and scarp present. The slope and base also have scattered concrete and other materials which may be hazardous. The southern access stairs have recently failed due to storm activity.

It is recommended that a new access track be built from the road edge of the carpark at the northern end to the beach to significantly lessen the potential likelihood of a serious accident occurring. There is a track further south from the one where the stairs to the beach have failed and this should become the preferred access track to the beach.

Conclusion and Recommendations

In essence four management options are presented.

(iv) Brush the upper slopes of the scarp adjacent to the section of the coast road closest to the beach. Place some signage to discourage human activities on the dunes in this vicinity. Eventually, should continued erosion take place, close the section of road most threatened at, or before 2024;

(v) Apart from (i) above, do nothing until the coast road fronting the Pool of Siloam is threatened and then decide to either let nature take its course; or,

(vi) Armour the western margin of the road;

(vii) Nourish the two topographic lows in the dune system, the gully and the blowout, to reduce the possibility of wave inundation and overwash in these areas.

Three recommendations are also made:

(i) Consider improving and relocating the beach access tracks at both ends of the embayment.

(ii) Maintain the causeway connecting Post Office Rock/Point William to the shore. Ensure the rock height is maintained and ensure that any threat of bypassing is addressed.

(iii) It is recommended that the Council invest in a UAV/drone such a Phantom 4 Professional and software such as PIX4D to process the images as this UAV device provides a cheap, effective method of regularly monitoring the site (and any other site) and producing high resolution aerial imagery.

Table 6.

Asset	Values	Risk – Outcome if no action taken	Timeframe if no action taken	Management Options	Timeframe for action	Feasibility (Cost capital / maintenance, access, effectiveness, longevity)	Trigger (How do we know when to take action?)	Comments / Discussion
Dune system	Environmental Social / Amenity	Dune will continue to erode, leading to risks for other physical and environmental assets		Do nothing	N/A	Impact on other infrastructure and environmental assets is likely by 2022-2024. Cost of works is $0 however ongoing impacts are likely to have a cost.		Community may be concerned about the changing landscape
				Monitor No physical response, however regular monitoring is undertaken to assess the rates of erosion and inform decision making	1-6 years	Commitment from State Govt to continue formal topo profiles. Purchase of UAV and software for regular Council monitoring. Cost to Council for purchase of equipment would be approx. $5000 - $6000.		
				Thatching / Brushing Laying vegetation on areas of dune to slow down erosion	Immediate and annual	See road discussion below	Sand on road	
				Sand nourishment at two topographically low sites in the dune system.	Within 1-5 years, and then 3 yearly.	Report contains discussion on likely volumes and feasibility. Also consider annual cost and whether this would be a long term solution.	Monitor low topographic sites and take action if a very significant storm or series of storms occur, or by ~2024-2026.	Not a long term solution IF dune erosion continues.

Asset	Values	Risk – Outcome if no action taken	Timeframe if no action taken	Management Options	Timeframe for action	Feasibility (Cost capital / maintenance, access, effectiveness, longevity)	Trigger (How do we know when to take action?)	Comments / Discussion
Dune system				Rock seawall at base of dune.	Never	Historically, the idea of building a seawall around this entire section of coast, from Snapper Point past Point William and around the northern beaches has been suggested. In 2009, the estimated cost was in the order of $5 million. In current dollars, the capital cost alone is expected to be in the order of perhaps $6-7 million. Due to the high energy environment and quality of rock available, a significant annual maintenance budget would also be required.		The benefits of this investment are not considered to be sufficient to warrant the capital or ongoing costs.
Dune System				Rock seawall to protect road and Pool of Siloam	20+ years	Capital cost would be likely in excess of $650,000 to $1.3 million.	When dune is all but gone	Benefits only if inundation of the Pool would lead to inundation of the town or parts thereof.
Native vegetation	Environmental Social / Amenity	Erosion will cause loss of native vegetation from the dune. Once dune is breached, storm surge is likely to	1-10 years depending on what exactly occurs next. For example, washover/inundation	See dune options above				

Asset	Values	Risk – Outcome if no action taken	Timeframe if no action taken	Management Options	Timeframe for action	Feasibility (Cost capital / maintenance, access, effectiveness, longevity)	Trigger (How do we know when to take action?)	Comments / Discussion
Native vegetation (continued)		impact on low lying vegetation behind the dune. Loss of vegetation will increase rates of erosion.	into blowout will have greater consequences than gradual erosion of dune system					
Beach access Stair access at Snapper Point as well as carpark / former road to tombolo / pedestrian access at Point William end.	Social / Amenity Council Infrastructure	Structures used for beach access will be unsafe and unsuitable for beach access. Formal access to the beach will be limited leading to an increase in "off track" access, causing further damage to vegetation and erosion	Present-3 years	Removal of unsafe access structures Installation of new structures in suitable locations with a design that accommodates the risks at this site.	Now (and continued maintenance)	Cost; Changing nature of the environment; Lack of regular supervision of these structures and possible impacts of storm damage.	Two major access points are either hazardous or broken. Action required now.	
Road – Bowman's Scenic Drive	Economic (tourism) Social Council Infrastructure Access to Waste Transfer Station	Road temporarily impassable due to sand transport	This process is ongoing at present.	Brush seaward dune slope and maintain. Place signage to prevent human damage.	Now	High	Sand inundation on road	

Asset	Values	Risk – Outcome if no action taken	Timeframe if no action taken	Management Options	Timeframe for action	Feasibility (Cost capital / maintenance, access, effectiveness, longevity)	Trigger (How do we know when to take action?)	Comments / Discussion
		Road permanently impassable at high point due to undermining	5-6 years	Close section of road	5-6 years	High		
		Road permanently impassable at low point due to flooding	20-30 years	Close road; OR construct seawall to protect road and Pool of Siloam.		Feasible to close road. Very expensive to construct seawall, and difficult due to lack of hard rock basement.		
Pool of Siloam (ecosystem / infrastructure)		Inundation 20+ yrs? Permanent.		Protect town if required.				
Inundation of township (via Pool of Siloam)	Vital infrastructure loss	Loss of portion of the town	20+ years	Construct seawall/dyke on the landwards (eastern) margin of the pool?		Significant capital costs.	When dune system is ~70% gone?	Further research required to examine exact nature of possible inundation of town if Pool of Siloam is inundated.
Groyne / tombolo	Infrastructure; Reduces erosion rate in the bay	Acceleration of beach and dune erosion	1-5 years	Place more rock at eastern (landwards) end of groyne/tombolo	Present		Action required now or within one year.	

References

Fotheringham, D., 2009. Shoreline erosion at Post Office Rock near Beachport South Australia. Coastal Management Branch Technical Report 2009/09.

Wright, L. D., and Short, A.D., 1984. Morphodynamic variability of surf zones and beaches: a synthesis. Marine Geology 56.1-4: 93-118.

Acknowledgement

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