

Appendix D Cliff and Slope Instability Walkover Field Survey

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From:	Madelaine Broadfoot, Paul Donaldson	To:	Kiama CMP Team
Date:	22 November 2019	CC:	Byron Robinson
Subject:	Geomorphological Walkover Field Survey and Preliminary Cliff/Slope Instability Exposure Assessment: Kiama's Rocky Coastline		

1.1 Overview

The Kiama coastline includes lengths of rocky coast which are subject to coastal and geotechnical processes. To date, no LGA wide assessment of the cliff and slope instability has been completed for the Kiama coast. In light of this, a first pass geological 'walk over' assessment was undertaken for the purpose of characterising Kiama's rocky coast and screening any potential cliff and slope instability risks to built assets or public safety which may warrant further detailed geotechnical investigation, conducted by a qualified geotechnical engineer, and following an industry recognised methodology like that outlined by the Australian Geomechanics Society (AGS, 2007).

1.2 Study Area

The Kiama LGA coastline extends south from Minnamurra River towards to Seven Mile Beach. The study area is characterised by a scenic rocky coastline with pocket beaches (with the exception of Seven Mile Beach) interspersed with prominent rocky headlands. The Kiama coast is made up of several different rock types, as detailed in geological mapping by Bowman & Stewart (1972) and Carr and Jones (2001), including (from north to south):

- Basalt
- Kiama Sandstone Member
- Blow Hole Latitie Member, which include the following:
 - Columnar-jointed facies
 - Rifle Range Sandstone Member
 - Tube and breccia facies
 - Sheet and lobe facies
- Westley Park Sandstone.

The geological materials that make up the coast substrates influence the physical form on the varying rocky geomorphology that is exhibited within the study region.

1.3 Aims and Objectives

A high level geomorphic assessment of cliff stability was conducted, based upon a review of literature, lidar and site inspection relating to the geology; coastal cliff/slopes types and failure mechanisms, and assets. The assessment will provide a first pass screening for cliff and slope stability, and will be used to develop recommendations for areas requiring a detailed geotechnical assessment; and interim planning controls.

1.4 Assessment Approach

Herein presents the results of a first pass field assessment of asset exposure to cliff and slope instability hazards. Safety risks / risk to life are also indicated (e.g., rock fall impacts, rock fishing risks, irresponsible community use of hazards areas – Kiama blowhole). The assessment included a three-day on-site survey / walk-over and a review of available information (inc. studies and recent Lidar), geological mapping, geomorphic descriptions of coastline, and key photos.

1.5 Summary of Exposure and Recommendations

The preliminary exposure assessment and recommendations for the Kiama coast are summarised below (from south to north) and locations presented in Figure 1.

1.5.1 Black Head at Gerroa

Land fronting the sewerage pump station on the western side of Black Head appears disturbed, it is recommended that the slope stability be monitored. The sewerage pump station on the eastern side of Black Head is situated on a weathered bedrock slope, that is fronted by a (potentially depositional) wide grassy terrace, some 5 metres above sea, it is recommended that the slope and erosion stability be monitored.

Properties on Stafford St near Black head reserve are close to the cliff edge, where bedrock is highly fractured and localised cliff regression rates look to be higher than elsewhere. New development or extensions proposed for this area should require geotechnical assessment, especially where allotment boundaries are in close proximity to cliff line. Additionally, residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work).

Burke Pde and some properties on this road are positioned on a low-lying terrace formed of alluvial/colluvial sediments, in front of bedrock cliffs, the land is possibly exposed to undercutting and slumping by wave action. Erosion of adjacent shorelines should be monitored, and formalised toe protection works may be warranted after a more detailed geotechnical investigation is conducted.

1.5.2 Gerroa to Gerringong farmland

No significant assets observed to be exposed to cliff and slope instability during the site visit.

1.5.3 Gerringong Harbour

No significant assets observed to be exposed to cliff and slope instability during the site visit.

1.5.4 Werri Beach and surrounds

The southern Werri Beach car park appears to be built on colluvium and exposed to wave, undercutting and slumping due to storm wave action (see Section 3). The adjacent shoreline to the car park should be monitored for erosion, if shoreline erosion occurs and threatens the car park asset, a more detailed geotechnical assessment may be warranted to determine the erosion susceptibility of the car park. Additionally, a more formalised toe protection works of the car park fronting the rocky slopes, may be warranted (as there appears to be some ad hoc / previous structure already there).

Geering St foreshore houses are located on a bedrock bluff slope. Under a future climate scenario, the toe of this slope may become exposed to wave action. If this occurs, some slope adjustment may occur in the event that highly weathered rock material and/or colluvial deposits become impacted by wave action. However, the geotechnical profile of this bedrock bluff slope is unknown at this stage. It is recommended that a geotechnical assessment be required for new development or extensions proposed where allotment boundaries adjoining the bluff slopes are located adjacent to the coastal hazard zones. Additionally, residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work).

The road, foot path and car park on Pacific Ave is potentially built on the same colluvium sediments as the southern Warri Beach car park and possibly exposed to wave, undercutting and slumping due to storm wave action. However, this area is possibly partially supported by bedrock, but will require further geotechnical investigation to confirm this risk, additionally, this area has been identified in the erosion mapping see Section 3.

1.5.5 Red Cliff to Loves Bay

This section of coast is farmland and Kiama Coast Walk, no fringing assets observed to be at risk slope/cliff instability during the site visit.

1.5.6 East Beach and surrounds

No exposure- stable sloping profile with private assets set back from the coast. The only Big4 asset identified to have a potential exposure appears to be built on bedrock.

1.5.7 Marsden Head to Kaleula Head

Residential properties on Boanyo Ave are located landward of a volcanic lava tube. The geological material underlying allotments adjacent to the exposed volcanic lava tube on the rocky shoreline is unknown. The underlying material may be unconsolidated sediments, consistent with exposures seaward of the property boundaries. If located on sediments/colluvium, these residential lots may be potentially exposed to hillslope process and associated geotechnical instability. Rock rubble fill placed seaward of properties suggest some instability has occurred in the past. A geotechnical assessment should be required for new development or extensions proposed within this area, particularly where allotment boundaries are near the cliff line. Additionally, residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work).

Some residential properties along Boanyo Ave are in close proximity to an undercut cliff and cave profile, the cliff face shows erosion from weathering and fracturing of cliff face profile. Future erosion of the cliff face profile will potentially expose the properties built above the cave. A geotechnical assessment should be required for new development or extensions proposed along Boanyo Ave, particularly where allotment boundaries are close to the cliff line. Additionally, residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work).

A large block fall was observed down slope of a cliff side house on Gwinganna Ave, on the southern side of Kaleula Head. Additionally, a stormwater pipe discharging from the property down slope of the house was observed. A geotechnical assessment should be required for new development or extensions proposed at this property and the landowner may consider redirecting stormwater outflows away from vertical cliff face. Additionally, residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work).

1.5.8 Kendalls Point to Church Point

Some localised rockfall and undercutting was observed at Kendalls Point. The steep slope may adjust in the future which could potentially expose the footpath and campground pool. It is recommended that the cliff top pathway be monitored for evidence of slope movement (e.g. cracking), a site specific geotechnical assessment is warranted, if this occurs.

At the showground and shared footpath on Church Point, evidence of slope movement exposing fill in places was observed, particularly where slope stabilisation works were absent. Recreational assets are at risk if slope continues to move in areas with over steepened slope profile (e.g. northern side of Church Point) and slope adjustment may expose sections of shared footpath and edges of the showground to geotechnical instability. Additionally, cracking of the shared footpath was observed on the southern side of Church point indicates slope movement. It is recommended that the cliff top pathway be further monitored for evidence of slope movement (e.g. cracking), a site specific geotechnical assessment is warranted, if this occurs.

1.5.9 Blow Hole Point to Kiama Harbour

On the NW side of the Blowhole, approx.120 m length of the Blowhole Point Rd, located immediately upslope of Stobo Rd, is situated on a highly weathered bedrock material. Evidence of minor rock falls was observed. The weathered vertical bedrock profile and proximity to wave action increases the roads exposure to slope instability. It is recommended that the cliff face be monitored for potential rock falls and slope movement and a site specific geotechnical assessment is warranted, if this occurs.

Undercutting of the Harbour seawall towards the SE was observed, it is recommended that a structural condition assessment be undertaken.

1.5.10 Pheasant Point

Properties located on and adjacent to the cliff face are exposed to cliff instability hazards. The thinly bedded sandstone exposed in the cliff face is relatively active, compared to the other sections of the Kiama coast. Houses cantilevered over the top of the actively eroding cliff face are highly exposed to geotechnical instability and increased exposure to undercutting where wave run up can reach active cliff face. A geotechnical assessment should be required for new development or extensions proposed along Pheasant Point Dr, where allotment boundaries are in close proximity and/or extend over the active cliff line. The residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work). Additionally, council should monitor cliff stability down slope of cliff side residential properties.

Pheasant Point Dr footpath located adjacent to the cliff face, spanning Black Beach Reserve toilet block to the Continental Pool ocean baths footpath is set above an actively eroding cliff face. In some sections a safety fence has been set up at the bottom of the cliff due to public safety risk of rock falls.

1.5.11 Bombo Headland to Cathedral Rocks

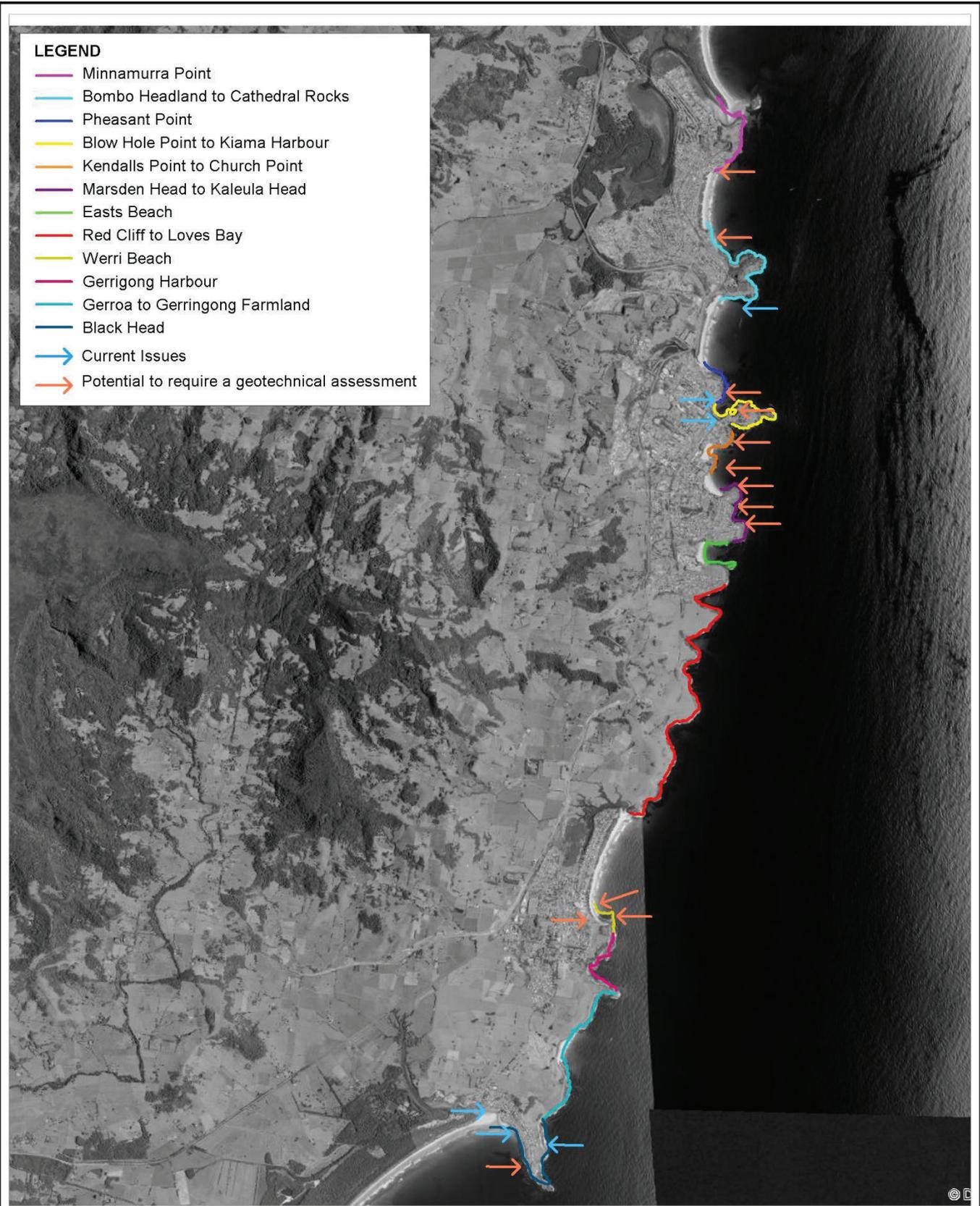
The southern side of Bombo Headland has an actively eroding cliff face. While no assets are in proximity to the eroding cliff face, there is a potential safety risk, however drainage upgrades and safety fencing have reduced this risk.

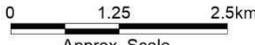
The cliff top of Cathedral Rocks is developed with residential properties. The cliff face on the south side of Cathedral Rocks is vertical and highly jointed, with residential properties are set back from the cliff face by some ~10 metres in this location. The rocky coast on the northern side of Cathedral rocks is steeply sloping, the north facing slopes may have instability as the cliff face adjusts towards a more stable slope that is consistent with the jointing. Residents should monitor dwellings for signs of movement (e.g. formation of

crack in brick work) and a geotechnical assessment should be required for new development or extensions proposed along Cliff Dr, where allotment boundaries are adjacent to the cliff line.

1.5.12 Minnamurra Point

Residential properties on Johnson St, southern side of Minnamurra Point are on low but steeply sloping cliff profiles. Evidence of slope instability was noted, including tree trunk adjustments and defects within built infrastructure. Additionally, observed fracturing of brick and concrete fencing indicates movement of the slope profile. A geotechnical assessment should be required for new development or extensions proposed at this location, particularly where allotment boundaries along Johnston Street are adjacent to the cliff line. Additionally, residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work).



<p>Title: Cliff and Slope Instability Walkover</p>	<p>Figure: 1</p>	<p>Rev: A</p>
<p>BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.</p>	<p style="text-align: center;">   Approx. Scale </p>	<p style="text-align: center;">  www.bmt.org </p>
<p>Filepath: "K:\N21130_Kiama_CMP\MI\Workspaces\DRG_XXX_Final_HazardWalkover_sects_001.wor"</p>		

1.6 Kiama walkover results

1.6.1 Black Head, Gerroa

Table 1 Black Head, Gerroa

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> Black Head forms an elongate rocky headland that extends in a south-easterly direction, with Seven Mile Beach adjacent to the southwest and mostly rocky terrain to the northeast. Residential suburb of Gerroa is located along headland and coastal slopes, adjacent to Crooked River Undeveloped reserve land also occurs at Black Head
Geology	<p>Rocky headland (Black Head)</p> <ul style="list-style-type: none"> Westley Park Sandstone Permian-age sandstone (bedrock) Volcaniclastic sediments, thickly bedded, cross stratification, fossils, jointing <p>Coastal barrier (Seven Mile Beach)</p> <ul style="list-style-type: none"> Dune, beach and shoreface sands, with estuarine sediments Extensive prograded barrier dune system, adjacent to headland with estuary entrance (Crooked River) abutting Black Head
Geomorphology	<ul style="list-style-type: none"> Elongate rocky headland, with vertical cliffs and wide rocky shore platform on the south side; grassy sloping foreshore on the north side
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> Marine processes – some wave undercutting (more dominant on the southern side) Hill slope processes (relatively dominate on the northern side)
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> Infrastructure Residential Asset
Infrastructure: Sewerage Pump Station (western side of headland)	<p>Pump station at Stafford St, located near to shore (Figure 2)</p> <ul style="list-style-type: none"> Land fronting looks disturbed and low lying. No obvious bedrock exposed. Slope fronting infrastructure may not be hard rock. Possibly exposed to undercutting by wave action and slumping.
Infrastructure: Sewerage Pump Station (eastern side of headland)	<p>Pumping station adjacent to car park off Headland Dr (Figure 3)</p> <ul style="list-style-type: none"> Pump station is situated on a weathered bedrock slope, that is fronted by a (depositional) wide grassy terrace, ~ 5 metres above sea level. No evidence of infrastructure being impacted by wave action or erosion (e.g. storm surge event, with elevated water levels) In the event of the fronting terrace showing signs of being eroded away, a more detailed coastal process investigation should occur.
Residential Asset: Stafford St	<p>Residential properties on Stafford St near Black head reserve</p> <ul style="list-style-type: none"> Residential houses located close to cliff edge, where localised cliff regression rates look to be higher than elsewhere (Figure 4) Bedrock highly fractured in this location, as per Figure 5
Residential Asset: Burke PDE	<ul style="list-style-type: none"> Some Burke Pde houses position on low lying terrace formed of alluvial/colluvial sediments, in front of bedrock cliffs (Figure 6). Land possibly exposed to undercutting and slumping by wave action.

Geotechnical Summary	
Infrastructure: Road, Burke PDE	<ul style="list-style-type: none"> Road in close proximity to the shore, located on low lying land formed of alluvial/colluvial sediments, as seen in an erosion escarpment (Figure 7). Possibly exposed to undercutting and slumping by wave action
Recommendation	
Infrastructure: Sewerage Pump Station (western side of headland)	Monitor slope stability through routine spot checks multiple times a year. This could include monitoring for evidence of slope movement (e.g. cracking in station foundation), a site specific geotechnical assessment is warranted, if this occurs.
Infrastructure: Sewerage Pump Station (eastern side of headland)	Monitor erosion and slope stability through routine spot checks multiple times a year, and aerial imagery analyses. This could include monitoring for evidence of slope movement (e.g. cracking in station foundation), or obvious landward shoreline changes (of the fronting terrace) observed in the aerial imagery. A site-specific geotechnical assessment is warranted, if any of these conditions occur.
Residential Asset: Stafford St	Require a Geological Survey of NSW (GSNSW) approved geotechnical assessment for new development or extensions proposed at 104 and 102 Stafford Street, where allotment boundaries are in close proximity to cliff line. Residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work)
Residential Asset: Burke PDE	Monitor erosion of adjacent shoreline. This could include shoreline change analysis using historic and current aerial imagery. Formalised toe protection works may be warranted.
Infrastructure: Road Burke PDE	As above.



Figure 2 Pumping Station on Stafford St, on the western side of the headland



Figure 3 Sewage pumping station off Headland Dr, on eastern side of headland



Figure 4 Property located near localised cliff regression

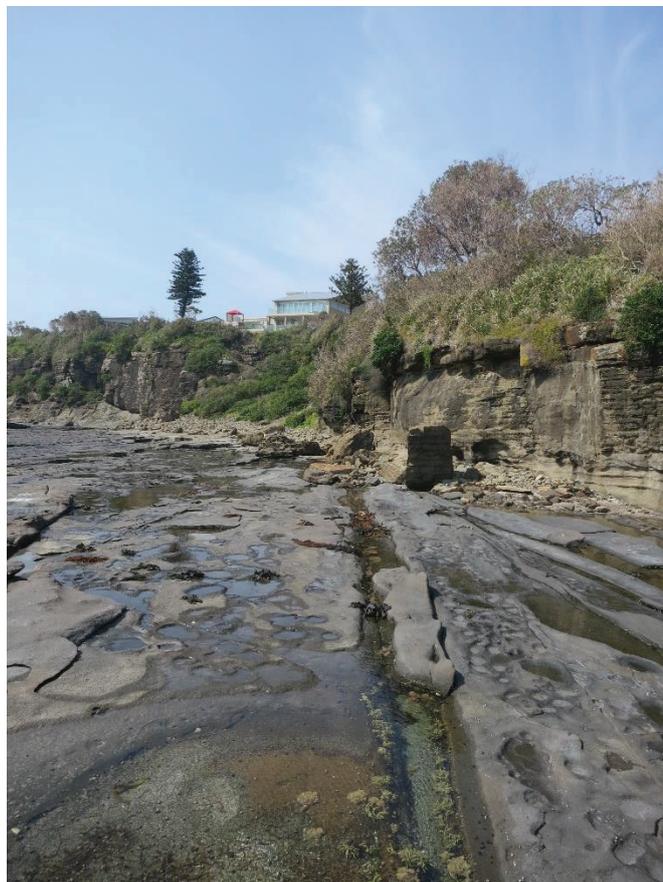


Figure 5 Fractured bedrock near Stafford St properties



Figure 6 Burke PDE foreshore houses on low lying erodible land, fronting bedrock cliffs



Figure 7 Unconsolidated exposed sediments forming low lying terrace at Burke PDE

1.6.2 Gerroa to Gerringong Farmland

Table 2 Gerroa to Gerringong Farmland

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> • Gerroa to Gerringong Farmland forms a rocky coast that extends in a south-north direction, this stretch of coast encompasses both Walkers and Shelly beach backed by the Gerringong Golf course and farmland. • No significant assets are located along this stretch of coast.
Geology	<p>Rocky headland areas</p> <ul style="list-style-type: none"> • Westley Park Sandstone <p>Coastal barrier (Walkers Beach)</p> <ul style="list-style-type: none"> • Dune, beach and shoreface sands
Geomorphology	<ul style="list-style-type: none"> • Grassy sloping foreshore, which transition into with vertical cliffs and wide rock platform towards the north (Figure 8).
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> • N/A
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> • No fringing assets only farmland and golf course
Recommendation	
	<ul style="list-style-type: none"> • N/A

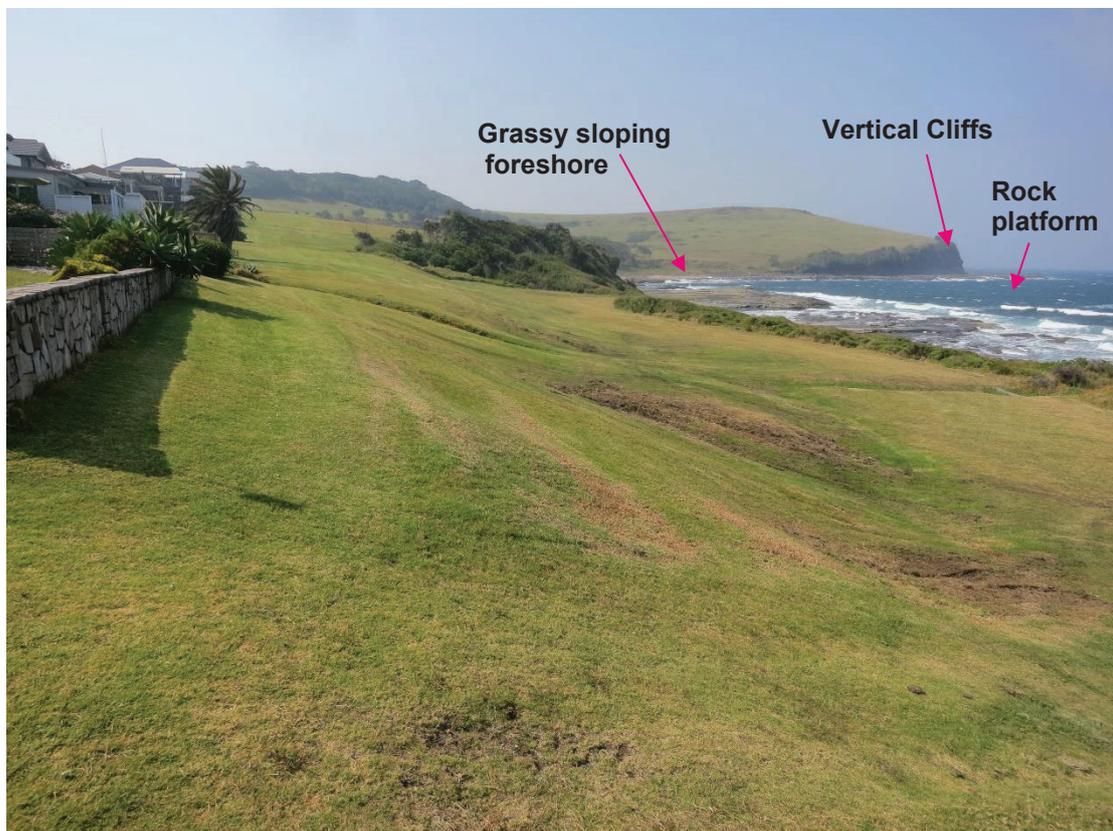


Figure 8 Gerroa to Gerringong Farmland

1.6.3 Gerringong Harbour

Table 3 Gerringong Harbour

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> Gerringong Harbour is in the residential suburb of Gerringong. The harbour is within a small embayment orientated to the south-east. The southern headland is elongated with tall vertical cliffs and to the north a wide rock platform is backed by vertical cliffs. The harbour amenities and structures include; the boat ramp, Cooke park, car park, fish cleaning facilities, public restrooms, pool, and rock wall (Figure 9). No significant assets were observed to be exposed during the site visit.
Geology	<p>Rocky headland areas</p> <ul style="list-style-type: none"> Westley Park Sandstone <p>Coastal sediments</p> <ul style="list-style-type: none"> Perched pebble to cobble beach
Geomorphology	<ul style="list-style-type: none"> Tall vertical cliffs, and wide rock platform (no assets on vertical cliff tops)
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> Hill slope processes Localised rock fall (Figure 10). Marine processes
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> No significant assets were observed to be exposed during the site visit.
Recommendation	
	<ul style="list-style-type: none"> N/A



Figure 9 Amenities and works at northern end of Gerringong Harbour



Figure 10 Localised rock fall at southern end of Gerringong Harbour

1.6.4 Werri Beach and Surrounds

Table 4 Werri Beach and Surrounds

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> South Werri Beach is located in the residential suburb of Gerringong and north Werri Beach is located in the residential suburb of Werri Beach. At south Werri Beach the amenities and community assets include public restrooms, car park, pool, footpath and roads. The headland at North Werri Beach has vertical cliffs with a wide rock platform. No public or private assets are located here (Figure 11)
Geology	<p>Rocky headland areas (Werri Beach headlands - south and north)</p> <ul style="list-style-type: none"> Westley Park Sandstone <p>Coastal barrier (Werri Beach and Werri Lagoon)</p> <ul style="list-style-type: none"> Dune, beach and shoreface sands, with estuarine sediments
Geomorphology	<ul style="list-style-type: none"> Vertical cliff face and wide rock platform to the east Grassy sloping profile to the west
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> Marine processes
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> Public Assets Residential Assets Infrastructure
Public Asset: South Werri Beach car park	<ul style="list-style-type: none"> Car park is built on colluvium and exposed to wave action (Figure 12 & Figure 13). Undercutting and slumping due to storm wave action may occur.
Residential Assets: Geering St	<ul style="list-style-type: none"> Geering St foreshores houses are located on a bedrock bluff slope (Figure 14). Under future climate scenarios, the toe of this slope may become exposed to wave action. If this occurs, some slope adjustment may occur in the event that highly weathered rock material and/or colluvial deposits become impacted by wave action. Note however, the geotechnical profile of this bedrock bluff slope is unknown at this stage. Area is possibly partially supported by bedrock, but may require further geotechnical investigation to confirm risk
Infrastructure and public Assets: Road, foot path and car park on Pacific Ave	<ul style="list-style-type: none"> Infrastructure located on the foreshore is potentially built on the same sediments as the south Werri Beach car park. Additionally, the proximity to wave action indicates possible exposure to undercutting and slumping by wave action. Area is possibly partially supported by bedrock, but may require further geotechnical investigation to confirm risk. Erosion risk has been identified in erosion mapping see Section 3 Coastal Erosion and Shoreline Recession
Recommendation	
South Werri Beach Car park	<ul style="list-style-type: none"> Monitor erosion of adjacent shoreline. If shoreline erosion occurs and threatens the car park asset, a more detailed geotechnical assessment may be warranted to determine the erosion susceptibility of the car park.

Geotechnical Summary	
	<ul style="list-style-type: none"> Formalised toe protection works of the car park fronting the rocky slopes, may be warranted.
House on Geering St	<ul style="list-style-type: none"> Require a geotechnical assessment for new development or extensions proposed where allotment boundaries adjoining the bluff slopes are located adjacent coastal hazard zones. Residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work)
Road, foot path and car park on Pacific Ave	<ul style="list-style-type: none"> Monitor erosion of adjacent shoreline. If shoreline erosion occurs and threatens the car park asset, a more detailed geotechnical assessment may be warranted to determine the erosion susceptibility of the car park.



Figure 11 North Werri Beach Headland



Figure 12 Colluvium sediment that the south Werri Beach car park is built upon



Figure 13 South Werri Beach car park



Figure 14 Geering St foreshore properties potentially exposed in the future



Figure 15 Pacific Ave, foot path and car park potentially exposed to undercutting and slumping by wave action in the future

1.6.5 Red Cliff to Loves Bay

Table 5 Red Cliff to Loves Bay

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> Red Cliff to Loves Bay extends from the residential suburbs of Gerringong in the south to Kiama Heights in the north. This section of the coast is highly popular for walking the Kiama Coast Walk, which extends from Loves Bay to Werri Lagoon This stretch of coast hosts spectacular geological outcrops, including volcanic rock (Blow Hole Latite) that are exposed on the cliff face overlying sandstone at Loves Bay (Figure 16) This stretch of coast is backed by farmland and no significant assets were identified as exposed.
Geology	<p>Rocky headland areas (Including Red Cliff and Bare Bluff)</p> <ul style="list-style-type: none"> Westley Park Sandstone Igneous dykes (Figure 17) Blow Hole Latite (sheet and lobe lavas) <p>Coastal Sediments</p> <ul style="list-style-type: none"> Perched cobble beach
Geomorphology	<ul style="list-style-type: none"> Vertical cliff face and wide rock platform (no assets on vertical cliff tops)
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> Hill slope processes Marine processes
Asset Exposure Summary	
Overview: Coastal Fringing Assets	No fringing assets only farmland and Kiama Coast Walk
Recommendation	
	<ul style="list-style-type: none"> N/A

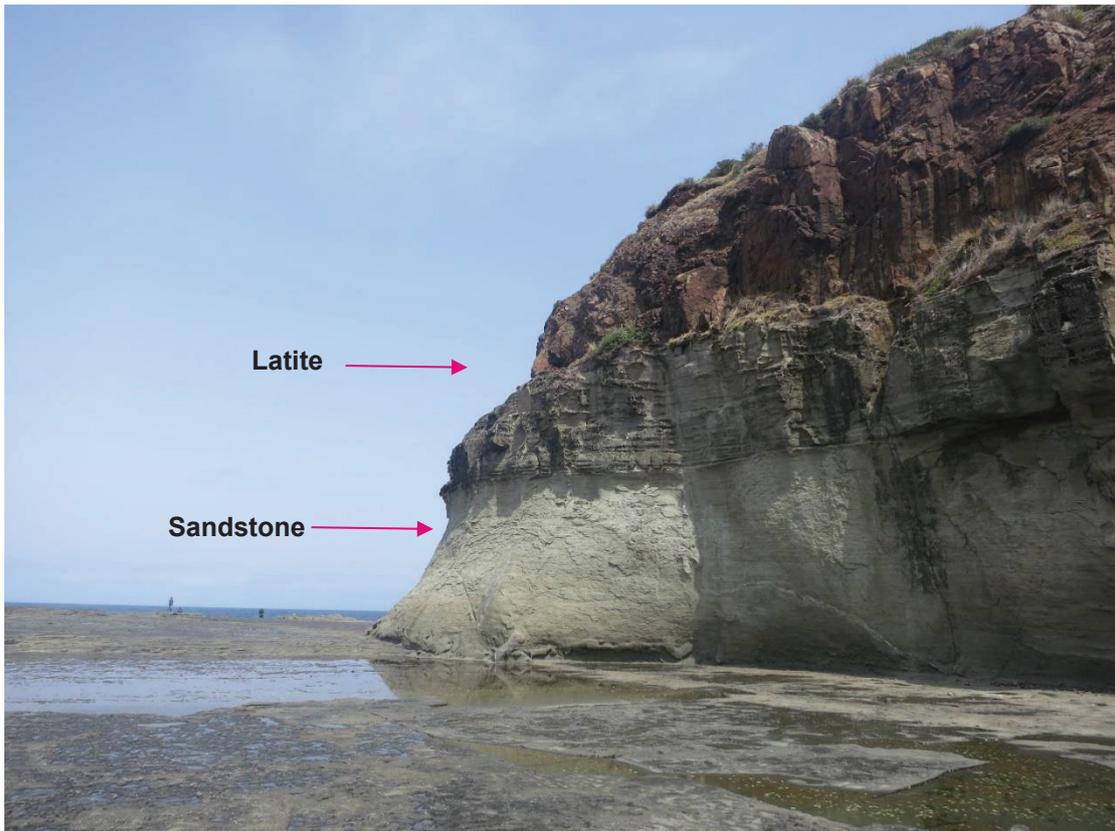


Figure 16 Blow Hole Latite over laying sandstone

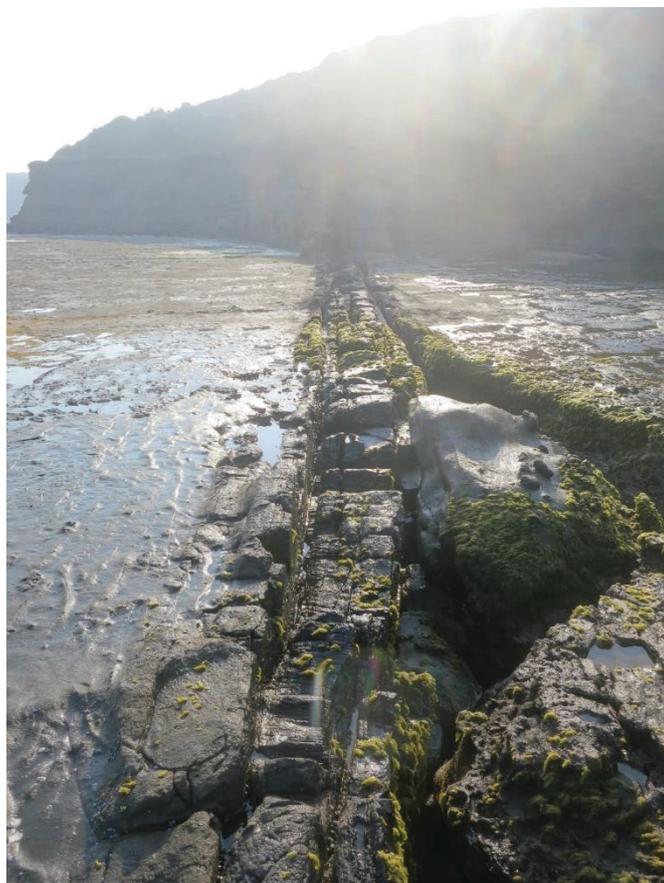


Figure 17 Igneous Dyke Intrusion

1.6.6 Easts Beach and Surrounds

Table 6 Easts Beach and Surrounds

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> • Easts Beach is located within residential suburb of Kiama and embayed by Marsden Head to the north and an unnamed headland to the south • The Big4 Holiday park owns/operates within majority of the embayment. While residential assets located on Marsden Head and the unnamed headland are set back from cliff face on the stable sloping profile (Figure 18).
Geology	<p>Rocky headland areas (Easts Beach Headlands, South and North)</p> <ul style="list-style-type: none"> • Blow Hole Latite (sheet and lobe lavas, tube and breccia, minor sandstone) <p>Coastal Sediments (Easts Beach)</p> <ul style="list-style-type: none"> • Dune, beach and shoreface sands
Geomorphology	<ul style="list-style-type: none"> • Grassy and rocky sloping profile • Some vertical cliffs (no assets on vertical cliff tops) (Figure 20)
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> • Hill slope processes
Asset Exposure Summary	
Overview: Coastal Fringing Assets	No exposure- stable sloping profile with private assets set back from the coast. The only Big4 asset identified to have a potential exposure appears to be built on bedrock (Figure 21).
Recommendation	
	<ul style="list-style-type: none"> • N/A



Figure 18 Easts beach (Marsden Head), stable rocky sloping profile with private assets set back from cliff face.



Figure 19 Easts beach (unnamed headland), grassy and rocky sloping profile with private assets set back from cliff face.



Figure 20 Northern vertical cliff face



Figure 21 Big4 assets built on suspected bedrock

1.6.7 Marsden Head to Kaleula Head (Little Blow Hole Coast)

Table 7 Marsden Head to Kaleula Head (Little Blow Hole Coast)

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> Marsden Head to Kaleula Head is a rocky coast, with Kendalls Beach to the north and Easts Beach to the south. This section of coast is within the residential suburb of Kiama This section rocky coast is densely populated, and in some instances residential buildings are built up to cliff face Little Blow, a popular tourist attraction that is located within this stretch of coast (Figure 22)
Geology	Rocky headland areas (Little Blow Hole Coast) <ul style="list-style-type: none"> Blow Hole Latite (tube and breccia, minor sandstone) Igneous dykes
Geomorphology	<ul style="list-style-type: none"> Undulating rock platform Colum formation Vertical cliff (Northern side of Kaleula Head) Caves Radial volcanic lava tube and cave
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> Localised rockfall Massive block fall Marine processes Hillslope processes
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> Public Assets Residential Assets
Residential Assets: 24, 26 Boanyo Ave	<p>Residential properties on Boanyo Ave are located landward of a volcanic lava tube (Figure 23)</p> <ul style="list-style-type: none"> Geological material underlying allotments along Boanyo Ave that are adjacent to an exposed volcanic lava tube on the rocky shoreline is unknown. The underlying material may be unconsolidated sediments, consistent with exposures seaward of the property boundaries (Figure 24). If located on sediments/colluvium, these residential lots may be potentially exposed to hillslope process and associated geotechnical instability. Rock rubble fill placed seaward of properties suggest some instability has occurred in the past.
Residential Assets: 2, 4 Boanyo Ave	<p>Residential properties on Boanyo Ave adjacent to a tall vertical cave (Figure 25 & Figure 26)</p> <ul style="list-style-type: none"> Properties (2 and 4 Boanyo Ave) are in close proximity to undercut cliff and cave profile Cliff face shows erosion from weathering and fracturing of cliff face profile. Future erosion of the cliff face profile will potentially expose the properties built above the cave.
Residential Assets: Gwinganna Ave	<p>Residential property on 4 Gwinganna Ave at the southern side of Kaleula Head (Figure 27)</p> <ul style="list-style-type: none"> Large block fall observed down slope of cliff side house (Figure 27) Stormwater flow from property discharged down slope of house (Figure 28). Stormwater discharge can promote hillslope processes and therefore increasing exposure to adjacent properties.

Geotechnical Summary Recommendation	
Residential Assets: Boanyo Ave	<ul style="list-style-type: none"> • Require a geotechnical assessment for new development or extensions proposed at 24 and 26 Boanyo Ave, where allotment boundaries are in close proximity to cliff line. • Residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work)
Residential Assets: Boanyo Ave	<ul style="list-style-type: none"> • Require a geotechnical assessment for new development or extensions proposed at 2 and 4 Boanyo Ave, where allotment boundaries are in close proximity to cliff line. • Residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work)
Residential Assets: Gwinganna Ave	<ul style="list-style-type: none"> • Require a geotechnical assessment for new development or extensions proposed at 4 Gwinganna Ave, where allotment boundaries are in close proximity to cliff line. • Residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work) • Landowner may consider redirecting stormwater outflows away from vertical cliff face

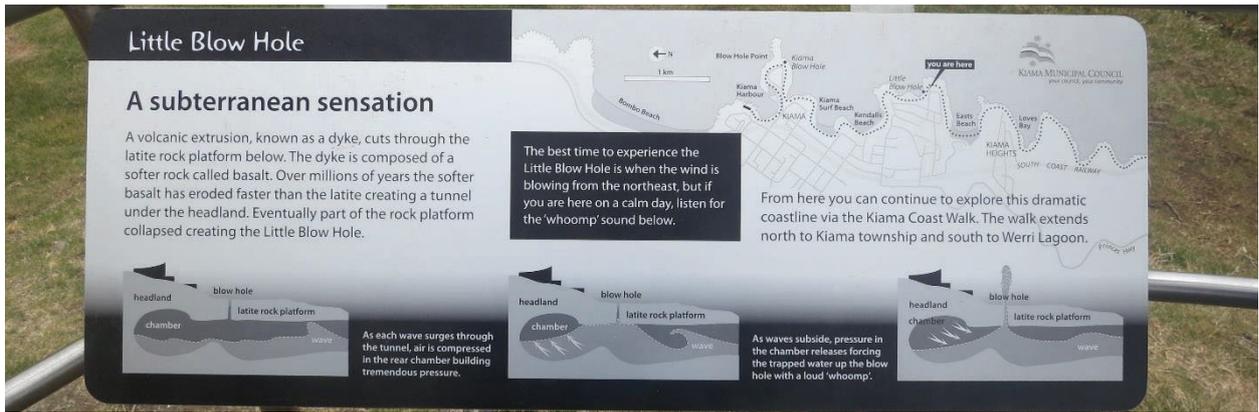


Figure 22 Little Blow Hole



Figure 23 Potentially exposed property on Boanyo Ave behind radial lave tube



Figure 24 Foreshore dwelling looks to be located on a localised occurrence of unconsolidated sediment (or anthropogenic fill?) that infill a volcanic lava tube on Boanyo Ave



Figure 25 Properties on Boanyo Ave built on cliff face are potentially exposed (southern side of cave)



Figure 26 Properties on Boanyo Ave built on cliff face, in close proximity to a vertical cave are potentially exposed (northern side of cave)



Figure 27 Residential properties on Gwinganna Ave at the southern side of Kaleula Head showing mega blocks fallen down slope of houses



Figure 28 Drainage pipe from property on Gwinganna Ave at the southern side of Kaleula Head discharging over headland

1.6.8 Kendalls Point to Church Point

Table 8 Kendalls Point to Church Point

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> Both Kendalls Point and Church Point are relatively truncated headlands within the residential suburb of Kiama. The two points embay the popular Kiama Surf Beach Kendalls Point is backed by a newly upgraded campground including cabins and a pool. A popular footpath lines the cliff top. The Kiama showground and football field are located on Church Point. Church Point has a modified landsurface. The headland likely comprised a more undulating terrain which has since been infilled to build upon. Rock works are in place to protect the seaward perimeter of the showground, football field and shared footpath on the southern side of Church Point (Figure 29).
Geology	<p>Rocky headland areas (Kendalls Point, Church Point)</p> <ul style="list-style-type: none"> Blow Hole Latite (tube and breccia, minor sandstone) Igneous dykes <p>Coastal Sediments (Kendalls Beach, Surf Beach)</p> <ul style="list-style-type: none"> Dune, beach and shoreface sands
Geomorphology	<ul style="list-style-type: none"> Steep fill slope Fill exposed at showground Over steepened slopes Sloping rock platform
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> Localised rock falls Hill slope processes Marine processes
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> Private Assets Public Assets
Private & Public Assets: Campground pool & footpath	<p>Campground and footpath on Kendall Point (Figure 30)</p> <ul style="list-style-type: none"> Some localised rockfall (Figure 30) and undercutting occurring at Kendalls Point The steep slope may adjust in the future which could potentially expose the footpath and campground pool.
Public Assets: Showground and shared footpath	<p>Kiama showground and shared footpath on Church Point</p> <ul style="list-style-type: none"> Evidence of slope movement exposing fill in places, where slope stabilisation works are absent (Figure 31) Recreational assets are at risk if slope continues to move in areas with over steepened slope profile (e.g. northern side of Church Point) (Figure 31). Slope adjustment may expose sections of shared footpath and edges of the showground to geotechnical instability (Figure 32) Stable rocky slope below areas of fill may provide protection from marine processes in most instances Observed cracking of the shared foot path on the southern side of Church point indicates slope movement (Figure 33)
Recommendation	

Geotechnical Summary	
Private & public Assets: Campground pool & footpath	<ul style="list-style-type: none"> • Monitor cliff top pathway for evidence of slope movement (e.g. cracking). A site specific geotechnical assessment is warranted, if this occurs
Public Assets: Showground and shared footpath	<ul style="list-style-type: none"> • As above



Figure 29 Protection works on the south side of Church Point



Figure 30 Kendalls Point footpath and localised rock fall



Figure 31 Over steepened slope showing evidence of movement



Figure 32 Exposed fill at the northern side of Church Point



Figure 33 Cracking of shared footpath at the southern side of Church Point

1.6.9 Blow Hole Point and Kiama Harbour

Table 9 Blow Hole Point and Kiama Harbour

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> Blow Hole Point and Kiama Harbour are located within the residential suburb of Kiama. Blow Hole point is a highly visited tourist attraction as it is home to the well-known “Kiama Blow Hole”. The southern edge of the point is relatively undeveloped compared to the northern side of the point, which includes holiday cabins, marina, café, car park, access roads and swimming pool. Kiama Harbour is embayed by Blow Hole Point to the SE and Pheasant Point to the NW. The harbour is a popular spot to launch boats and visit the foreshore. The 2016 east coast low damaged infrastructure around the harbour and inside the marina.
Geology	<p>Rocky headland areas (Blow Hole Point)</p> <ul style="list-style-type: none"> Blow Hole Latite (columnar jointed lava) Igneous dykes <p>Coastal Sediments (Kiama Harbour)</p> <ul style="list-style-type: none"> Perched cobble beach
Geomorphology	<ul style="list-style-type: none"> Sloping rocky shore Blow hole Vertical cliffs Rocky platform
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> Hillslope processes Marine processes
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> Infrastructure
Infrastructure: Blow Hole Point Rd	<p>Blowhole Point RD, adjacent to Stobo RD, Blowhole Point (Figure 34)</p> <ul style="list-style-type: none"> On the NW side of Blowhole Point A 120 metre length of Blowhole Point RD, located immediately upslope of Stobo Rd, is situated on a highly weathered bedrock material. Evidence of minor rock falls was noted. The weathered vertical bedrock profile and proximity to wave action increases the exposure to slope instability.
Infrastructure: Harbour wall	<p>Harbour seawall, SE area (Figure 35)</p> <ul style="list-style-type: none"> Undercutting the harbour seawall was observed.
Recommendation	
Infrastructure: Blow Hole Point Rd	<ul style="list-style-type: none"> Monitor vertical cliff face for potential rock falls and slope movement A site specific geotechnical assessment is warranted, if this occurs
Infrastructure: Harbour wall	<ul style="list-style-type: none"> Undertake a coastal engineering condition assessment



Figure 34 Highly weathered rock below Blowhole Point Rd



Figure 35 Undercutting of harbour wall by marine processes

1.6.10 Pheasant Point

Table 10 Pheasant Point

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> Pheasant Point is a relatively truncated rocky point, located within the suburb of Kiama. The Point is bound by Kiama Harbour to the south and Bombo Beach to the north. Pheasant Point has been developed, with residential properties occupying most of the point. Several properties extend to the cliff face (Figure 36) The geological profile of the Pheasant Point cliffs is highly jointed and shows recent rock fall activity Sections of the rock platform have been fenced due to recent rock fall activity. (Figure 37)
Geology	Rocky headland areas (Pheasant Point) <ul style="list-style-type: none"> Kiama sandstone Igneous dykes, weathered below rock platform (Figure 38))
Geomorphology	<ul style="list-style-type: none"> Wide rocky platform Tall vertical cliffs
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> Hillslope processes Marine processes Rock falls
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> Residential Assets Infrastructure Public Asset
Residential Assets: Houses, Pheasant Point Dr	<p>Properties located on and adjacent to the cliff face are exposed to cliff instability hazards</p> <ul style="list-style-type: none"> The thinly bedded sandstone exposed in the cliff face is relatively active, compared to the other sections of the Kiama coast Houses cantilevered over the top of the actively eroding cliff face are highly exposed to geotechnical instability (Figure 36) Exposure to undercutting where wave run up can reach active cliff face The weathered dyke below rock platform and set back in the cliff line has increased the rate of weathering of the cliff profile (Figure 38).
Infrastructure & Public Assets: Pheasant Point Dr footpath	<p>Pheasant Point Dr footpath located adjacent to the cliff face, spanning Black Beach Reserve toilet block to the Continental Pool ocean baths (Figure 39)</p> <ul style="list-style-type: none"> Pheasant Point Dr footpath set above an actively eroding cliff face. In some sections a safety fence has been set up at the bottom of the cliff due to public safety risk of rock falls
Recommendation	
Residential Assets: Houses, Pheasant Point Dr	<ul style="list-style-type: none"> A Geotechnical assessment is required for new development or extensions proposed along Pheasant Point Dr, where allotment boundaries are in close proximity and/or extend over the active cliff line. Residents to monitor dwellings for signs of movement (e.g. formation of crack in brick work). Council to monitor cliff stability down slope of cliff side residential properties.
Infrastructure & Public Assets:	<ul style="list-style-type: none"> Maintain safety fencing and signage along areas with high rock fall activity

Geotechnical Summary	
Pheasant Point Dr footpath	



Figure 36 House cantilevered over cliff face with evidence of rock falls



Figure 37 Pheasant Point actively eroding cliff face

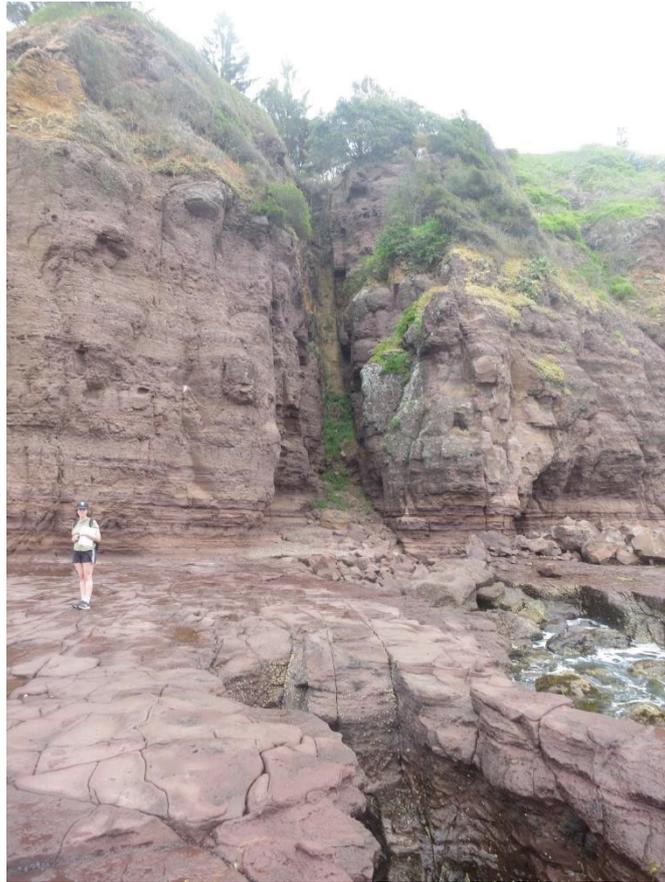


Figure 38 Igneous dyke weathered below rock platform and into cliff face



Figure 39 Pheasant Point Dr and footpath

1.6.11 Bombo Headland to Cathedral Rocks

Table 11 Bombo Headland to Cathedral Rocks

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> Bombo Headland is within the suburb of Bombo and is bound by Bombo Beach to the south and the Boneyard to the north. Bombo Headland was formerly used as a quarry which is now heritage listed. Currently Sydney Water operates the Bombo sewage treatment plant on the headland, at the time of the site visit works were being undertaken on the headland (Figure 41). The southern side of Bombo Headland has an actively eroding cliff face. While no assets are in proximity to the eroding cliff face, there is a potential safety risk. Drainage upgrades and safety fencing have addressed this risk (Figure 40). Cathedral Rocks is a unique section of rocky coast, located north of Bombo Headland. It falls within the suburb of Kiama Downes, and is adjacent to Cameron Boyd reserve to the south and Jones Beach to the north.
Geology	<p>Rocky headland areas (Bombo Headland, Cathedral Rock)</p> <ul style="list-style-type: none"> Bombo Latite (columnar jointed lava) <p>Coastal Sediments (Bombo Beach)</p> <ul style="list-style-type: none"> Dune, beach and shoreface sands
Geomorphology	<ul style="list-style-type: none"> Vertical cliff faces to the south Sloping cliff faces to the north
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> Hillslope processes
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> Private assets Residential Assets
Residential Asset: Houses, Cliff Dr	<p>Residential properties above Cathedral Rock section of coastline</p> <ul style="list-style-type: none"> The cliff top of Cathedral Rocks is developed with residential properties. Several properties are in close proximity to the cliff edge (Figure 42). The cliff face on the south side of Cathedral Rocks is vertical and highly jointed (Figure 44). Residential properties are set back from the cliff face by some ~10 metres in this location (i.e. Cliff Drive). The rocky coast on the northern side of Cathedral rocks is steeply sloping. The north facing slopes may have instability as the cliff face adjusts towards a more stable slope that is consistent with the jointing (Figure 45)
Recommendation	
Residential Asset: Houses, Cliff Dr	<ul style="list-style-type: none"> Residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work) Require a geotechnical assessment for new development or extensions proposed along Cliff Dr, especially where allotment boundaries are adjacent to the cliff line.



Figure 40 Bombo Headland, southern side actively eroding



Figure 41 Works being undertaken during the time of the assessment, Bombo Headland



Figure 42 Cathedral Rocks



Figure 43 Vertical cliff face failing due to hill slope processes



Figure 44 Highly jointed vertical cliff face on the southern side of Cathedral Rocks



Figure 45 Steeply sloping cliff face on the northern side of Cathedral Rocks



Figure 46 Residential properties on the Cathedral Rock cliff top exposed to potential hazards

1.6.12 Minnamurra Point

Table 12 Minnamurra Point

Geotechnical Summary	
Overview	<ul style="list-style-type: none"> • Minnamurra Point separates Jones Beach to the south and the Minnamurra river entrance to the north. It is located within both the Kiama Downes and Minnamurra communities. • The northern side of the point (Minnamurra) hosts an undeveloped reserve (Figure 47). The north to east facing shoreline comprises cliffs, varying from sloping to vertical profiles, with some rock falls apparent (Figure 48). • The southern side of the point (Kiama Downes) is developed with residential properties. Some properties are located on adjacent to low, steep coastal slopes (Figure 49).
Geology	<p>Rocky headland areas (Minnamurra Point)</p> <ul style="list-style-type: none"> • Bombo Latite (columnar jointed lava) <p>Coastal Sediments (Jones Beach, Minnamurra Estuary)</p> <ul style="list-style-type: none"> • Dune, beach and shoreface sands
Geomorphology	<ul style="list-style-type: none"> • Vertical cliffs • Rock platform • Sloping profile
Coastal Cliff / Slope Processes	<ul style="list-style-type: none"> • Fallen rocks • Hillslope processes
Asset Exposure Summary	
Overview: Coastal Fringing Assets	<ul style="list-style-type: none"> • Residential Assets
Residential Assets: Houses, Johnson St	<p>Residential properties on Johnson St, southern side of Minnamurra Point</p> <ul style="list-style-type: none"> • The properties on this side of Minnamurra Point abut low, yet steeply sloping cliff profiles. • Evidence of slope instability was noted, including tree trunk adjustments and defects within built infrastructure (Figure 49) • Fracturing of brick and concrete fencing indicates movement of the slope profile (Figure 50 & Figure 51)
Recommendation	
Residential Assets: Houses, Johnson St	<ul style="list-style-type: none"> • Require a geotechnical assessment for new development or extensions proposed along Johnston Street, where allotment boundaries are adjacent to the cliff line. • Residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work)



Figure 47 Minnamurra river entrance and reserve



Figure 48 Vertical cliffs and localised rock fall at the eastern edge of Minnamurra point



Figure 49 Houses located on steep slope, Johnson St south side of Minnamurra Point



Figure 50 Fracturing of property fences due to instabilities, Johnson St south side of Minnamurra Point



Figure 51 Fracturing of property fences due to instabilities Johnson St south side of Minnamurra Point

1.7 References

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