22 March 2022

LIMESTONE CLIFF RISK ASSESSMENT

GRACETOWN, PREVELLY, GNARABUP, GRUNTERS, WESTERN AUSTRALIA

INSPECTION AND RISK ASSESSMENT

Shire of Augusta Margaret River

PER2021-0300AB Rev0

PER2021-0300AB		
Date	Revision	Comments
22 December 2021	A	Draft Report
22 March 2022	0	Final following site workshop and comments

Table of Contents

Appendices

1 INTRODUCTION

On 7 November 2021 CMW Geosciences Pty Ltd (CMW) was commissioned by the Shire of Augusta Margaret River (SAMR) by way of a signed contract to carry out Contract RFQ 082101. This was to conduct a Limestone cliff stability assessment.

Details of the scope of work and methodology are documented in our response to the RFQ 082101 dated 13 September 2021.

In summary, the commission required the consultant (CMW) to provide the Shire of Augusta Margaret River (SAMR) with advice and information as follows:

- Review the Golder 2017 Limestone Cliff Stability Assessment report, the CMW 2019 Limestone Stability Assessment and the Huzzas Cliff Geotechnical Assessment report prepared by ATC Williams.
- Undertake a site inspection to assess whether previously assessed risk levels have changed with respect to recreational users and Shire Assets in connection with limestone cliff instability.
- Undertake a rockfall risk assessment of the Wallcliffe Cliff. As this feature is closed to the public the scope of work requires the risk assessment be undertaken specifically for contractors engaged to undertake the removal of existing climbing bolts.
- Preparation of draft report to confirm or amend previous recommendations for each site.
- Carry out a workshop with relevant shire staff to review the risk assessment and recommendations. This workshop was undertaken on site on 17 January 2022, attended by John McKinney and three other representatives of SAMR at the Huzzas cliff (GC3-50, Gnarabup Headland (GN3-40, GN3-90 and GN3-100) and Marmaduke Point (GR2-20)/. A representive of the Department of Biodiversity Conservation and Attractions (DBCA) also attended the site visit to GC3-50 at the invitation of SAMR as this cliff instability straddles an area under the control of SAMR (northern part) and DBCA (southern part).
- Preparation of final report with detailed recommendations for remedial works where required (this report).

This report contains the review, assessment of current conditions and risk mitigation works.

In addition, SAMR requested a sign audit be undertaken as part of the inspection, to note any rockfall hazard or related signs which might require replacement or be required due to a hazard not being adequately signed.

The limestone cliff stability inspection was made by Matthew Tutton, Senior Principal Engineering Geologist and Amy Tsagopoulos, Senior Engineering Geologist from CMW on 18 November 2021 to 21 November 2021. Matthew Tutton attended the site workshop on the afternoon of Monday 1`7 January 2022.

2 PROJECT BACKGROUND

A few earlier studies have been undertaken for the Shire of Augusta Margaret River to quantify geotechnical risk to people and assets from coastal cliff stability and rockfalls.

These earlier studies include a recent study undertaken for SAMR by Golder Associates and reported upon in May 2017. The title of the report relating to the May 2017 study is “Limestone Cliff Stability Assessment”. This was a comprehensive study of limestone cliff geology and stability and had a particular focus relatively risk to people and to SAMR assets in the context of sea level rise at Gracetown, Prevelly, Gnarabup Headland and Grunters Beach.

An additional study was undertaken by CMW in 2019, where six ‘higher’ risk locations identified in the Golder 2017 report were re-assessed and some remediation/risk mitigation works were designed.

In March 2021, a geotechnical assessment was conducted by ATC Williams on Huzzas Cliffs, of which some information is relevant to this current study.

Part of the scope of work for the current study was to review these reports and to re-assess conditions at the relevant locations.

3 PROVIDED INFORMATION

The following information was provided and has been relied upon in preparing this report.

- Golder Associates 2017; Limestone Cliff Stability Assessment - prepared for the Shire of Augusta Margaret River (reference 1666765-001-R-Rev0, dated May 2017)
- Baynes Geologic 2006; Surfers Point Redevelopment, Geotechnical Constraints - prepared for the Shire of Augusta Margaret River
- Gordon Geological Consultants 2002; Huzza Beach, Gracetown Memorial Site and Huzza Beach Gracetown Stability of Steps - prepared for the Shire of Augusta Margaret River
- Gordon Geological Consultants 2005; Huzzas Cliff Inspection 2005 - prepared for the Shire of Augusta Margaret River
- CMW Geosciences 2019; Limestone Stability Assessment – prepared for the Shire of Augusta Margaret River (reference PER20219-0229AARev1 dated 25 October 2019)
- ATC Williams 2021; Huzzas Cliffs, Cowaramup Bay, WA, Geotechnical Assessment – 2020 (reference 120225.01R02, dated 25 March 2021)

4 SITE INSPECTION AND RECOMMENDATIONS

4.1 Preamble

The site inspection was undertaken between 18 November and 21 November 2021, jointly by Amy Tsagopoulos and Matthew Tutton of CMW.

Observations are described below and are illustrated in Appendix A. Recommendations are also provided in this section of the report. A quantitative risk assessment has also been undertaken for all locations and the details of this risk assessment are provided in Appendix B. The method of calculating risk is principally in accordance with the Landslide Risk Management Guidelines AGS 2007. It tries to mirror the approach taken by Golder 2017 however with changing conditions some of the inputs are different. Definitions of the various terminology are reproduced in Appendix D for convenience. Note the criteria for acceptable and tolerable risk needs to be determined by SAMR however guidance in AGS 2007 suggest the following limits for tolerable risk for existing slopes.

Tolerable Risk for Loss of Life (existing slopes)

Risk	**Tolerable Annual Probability**
Individual Most at Risk	1.0×10^{-4}
Societal Risk	1.0×10^{-5}
Cumulative Individual Risk	No guidance provided

Cumulative Individual Risk is provided only for comparison purposes. All risks provided in Appendix B relates to the observed conditions before any risk mitigation or remedial works are undertaken.

SAMR officers should review the assumptions presented in Appendix B used to calculate risk to see whether user numbers who may transit or use a beach, stairs, etc., concur with their estimate of usage and exposure (time in the hazard area).

Columns coloured 'green' in the risk assessment are those where remedial/risk mitigation works beyond signage, brushwood and revegetation are recommended.

Appendix A outlines some recommendations (annotated photographs) to potentially decrease the risk at that location. Appendix B presents the assessed level of risk for the Individual Most at Risk and also documents recommendations to reduce the risk levels presented.

The sub-section below discusses those locations where the assessed level of risk has changed. It also discusses hazards and associated risks at new locations introduced since 2017.

The 'Site ID' originally used by Golder in their 2017 report continues to be used in this assessment. The letters GC, PR, GN and GR refer to Gracetown, Prevelly, Gnarabup and Grunters respectively. As the Golder 2017 report extensively describes the hazard, and indeed the geology, geological process and coastal processes that have shaped this coastline we have not re-described the hazard in detail or reiterated the geology. If details are required reference should be made to the 2017 Golder report. The current report instead present changes that have occurred since either the Golder 2017 inspection or the CMW 2019 inspection, it is documents assessed levels of rockfall or cliff instability risk and where required, makes recommendations to mitigate or manage risk.

4.2 Site ID: GC3-50

Refer Slides 1 and 2 (Appendix A) for location details and Slides 3 and 4 for recommended risk mitigation works.

Note the risk assessment only refers to the part of Huzzas Cliff (GC3-50) within SAMR controlled land. The majority of Huzzas Cliff (approximately the western 75%) falls under National Park jurisdiction (Department of Biodiversity, Conservation and Attractions (DBCA)). Recommnedation shown on Slides 3 and 4 were developed during the on site workshop on 17 January 2022 attended by representatives from SAMR, DBCA and CMW.

The location was inspected during a very low tide and on an exceptionally still day (almost no swell). It is apparent coastal erosion due to wave attack has occurred during the winter of 2021 cutting into palaeosol material and limestone colluvium in front of the notch that forms the Huzzas cliff overhang. This has mainly occurred at the eastern end of GC3-50. The erosion has caused the existing fence to be undercut and it is broken at its eastern end (refer Slide 2, Appendix A).

The risk from this hazard has increased since the 2017 Golder inspection.

It is noted that the existing fence is too close to the hazard to keep people out of the hazard zone should a major collapse occur. The problem is that there is not enough space to move the fence seaward by any substantial distance. Risks have been assessed based on the current fence position.

It recommended that 'Informative' signage be installed in positions similar to those indicated on Slide 4. The informative signs need to be positioned such that the hazard at Huzzas cliff can be seen from the sign, and the sign recured to rock and sufficiently high up the beach not to be washed away or damaged during stormy weather. The signs should clearly explain (ideally through photographs, and diagrams) the Huzzas Cliff hazard and present a message to discourage people from traversing in front Huzzas Beach particularly at times when a high tide or large swell forces people up to and potentially inside the fence fronting the cliff and therefore well into the hazard zone. The safest passage (with respect to rockfall risk) is along the waterline at low tide.

It is also recommended a large "Rockfall Hazard Area" sign is installed each end of GC3-50 to further warn the public who traverse the area.

Finally, it is recommended that the existing fence fronting both SAMR and DBCA controlled parts of the cliff, which is damaged, is replaced with a more resilient fence similar to the one installed by SAMR at Riflebutts beach. This replacement fence should be extended eastwards to prevent access to an area of recent coastal erosion and should be installed slightly seaward of the existing fence where practical to keep the public out of the hazard zone as far as possible. The proposed alignment of the fence is shown on Slide 3. It is noted it would not be practical to install a fence sufficiently set back from the undercut cliff to keep the public entirely out of the hazard zone from larger events. The risk from larger and less frequent events can be mitigated but not eliminated by discouraging access through signage and education (informative signage).

4.3 Site ID: GC4-60

Refer Slide 5 No change from 2017 inspection.

4.4 Site ID: GC5-75

Refer to Slides 6 and 7.

The overhang discussed as a high-risk area following the 2017 and 2019 inspections was removed in 2020. As such the risk from this hazard has been reduced significantly for the public walking on the beach and exiting the bottom of the Southpoint carpark stairs. There is evidence of pedestrian traffic on the slope face causing erosion. It is recommended that brushwood be placed on this trafficked area to encourage vegetation growth and to discourage ascending or descending the steep and friable slope below this hazard (refer Slide 7).

4.5 Southpoint Carpark Stairs

Refer Slide 8. Observation of minor coastal erosion made at this location.

It is recommended to place brushwood on parts of slope where vegetation has been impacted to mitigate against the future risk of slope instability. It is recommended SAMR monitors the situation regarding erosion of the beach and places riprap or other beach erosion control measures on an ‘as and when required’ basis. It is also recommended that stanchions to stairs be extended and secured to new footing if they become undercut.

4.6 Site ID: GC6-15

Refer Slide 9. This hazard area was identified as a high priority area in the 2017 Golder report as a lookout attached to the Southpoint carpark stairs was founded on a potentially unstable block of limestone. Since that time the risk to the stairs has been significantly improved as the lookout was removed and the stairs are set well back from the unstable block, such that they are unlikely to be adversely affected if the potentially unstable block was to fall. The most significant risk is now to beach users, specifically people traversing the rocky foreshore below the unstable block. The risk to beach users is less than the tolerable annual probability risk levels discussed in Section 4.1 above. There is currently adequate signage on the beach below this hazard.

4.7 Site ID: GC6:50

Refer Slides 6 and 10.

This is a new location not included in the 2017 or 2019 Limestone Cliff Stability assessment reports. If a rockfall was to occur in this area, it will likely not reach the beach in one piece, with the vegetation breaking the fall. However, there is evidence that this area is used as a pathway. It is recommended to add brushwood to encourage vegetation growth and to discourage pedestrian traffic up or down this slope below the carpark. It is also recommended that a small ‘Rockfall Hazard Area’ sign be installed on the foreshore below the hazard.

4.8 Site ID: GC6;60

Refer Slides 11, 12 and 13.

Vegetation is becoming more established since the 2017 and 2019 inspections and the level of risk remains principally unchanged since 2017.

4.9 Site ID: GC6-100

Refer Slides 14 and 15.

Level of risk unchanged since 2017.

4.10 Site ID: PR3-165

Refer Slides 16, 17 and 18.

No change to level of risk since 2017 assessment.

4.11 Site ID: PR4-30

Refer Slides 16, 19, 20 and 21.

The risk in this area has been reduced from 2017 due to the removal or the lookout and bench. Risk levels have been reduced from the 2019 assessment based on signage and regrowth of vegetation likely being effective in reducing the number of people on and above the overhang. This has been known to occur in the past during surf events, when the rock ledge has been used by spectators. It is imperative that during events that attract a large number of spectators that security be used to stop people from accessing the overhang, this also would include media personnel. The assessed levels of risk are based on up to 5 people (at once) using the ledge as a spectator platform for up to two events each year each for a 5-hour period. The resultant risk is tolerable using the criteria set out in Section 4.1 of this report. It is still a high level of risk and as such these numbers should be reduced by using security during major events to prevent access onto this ledge.

4.12 Site ID:PR4-40

Refer Slides 16 and 22.

Level of risk unchanged since 2017.

4.13 Site ID:PR4-100

Refer Slides 23, 24 and 25.

The risk in this area has increased due to the re-assessment of the hazard and impact zone. There is evidence of pedestrian traffic including on the overhang itself (refer Slide 25). To reduce the risk, it is recommended that pedestrian traffic be reduced and ideally stopped in this area through the use of ‘Rockfall Hazard Area’ signs (set at a suitable height for eye-level or angled similar to those used at PR4-30 and GN5-5) and to place brushwood to reduce traversing informal paths and to encourage vegetation growth. Fencing could be improved to further reduce entry into this area from the picnic area at Mainbreak (refer Slide 25).

4.14 Site ID:PR5-50

Refer Slides 23 and 26.

Level of risk unchanged since 2017.

4.15 Site ID: PR5-150

Refer Slides 23 and 27.

Level of risk unchanged since 2017.

4.16 Site ID: PR6-85 and PR6-140

Refer Slides 28 through to Slide 38.

This is a major hazard area and there is much evidence of ongoing rockfalls (refer Slides 30, 35. 36 and 38). The most recent is a rockfall that occurred in August 2021 (refer Slide 35) and resulted in about 15 m^3 of limestone falling onto the beach and spilling out about 8 m across the beach from the cliff. This occurred after the erection of a substantial fence earlier in 2021 to discourage public access and extensive warning signs including an informative sign panel (refer Slides 28, 32 and 33).

The assessed risks are based on a reduced number of people accessing the hazard zone and are less than those previously assessed in 2019 before mitigation measures were undertaken. All the time people continue to access this hazard zone (ignoring the fence) a residual level of risk will exist. It should however be noted that the fence is substantial and extends from the cliff into the water and as such the hazard zone cannot be entered from the south without either deliberately ducking under or climbing over the fence. The hazards and risk are also well signed (refer Slide 33).

It should nonetheless be noted that at the time of our November 2021 site inspection five people were within the hazard area having crossed the barrier to the south. One person was sunbathing directly underneath the source area of the rockfall which had occurred in August 2021.

4.17 Site ID: GN1-25

Refer Slides 39 and 40

Level of risk unchanged since 2017.

4.18 Site ID: GN1-50

Refer Slides 39 and 41

Level of risk unchanged since 2017.

It is recommended at a “Rockfall Hazard Area” sign be erect on the beach either side of the hazard of this hazard to be viewed when approaching from both the north and south. The signage will also be applicable to hazard GN1-25.

4.19 Site ID: GN3-40

Refer Slide 42, 43 and 46

Level of risk unchanged since 2017.

This is an overhang ledge which could collapse. It should be noted that this hazard is closely associated with GN3-90 and the whole area below the lookout in this area is heavily eroded and people are traversing along the ledges below the lookout. Extensive measures to discourage public access, manage erosion and inform the public of risks are proposed for the whole of the area below the lookout. Refer specifically to Slides 42 to 46 for details.

It should be noted that whilst the risk levels have not increased since 2017, ongoing erosion and increased public access will see these levels increase. Reference to Slide 42, which utilised an October 2021 aerial image clearly shows the extent of eroded ground west and north or the lookout, ground that comprises weak friable limestone/sand. Measures are needed to prevent further erosion and limit public access within the hazard zone to stop the risk levels from increasing.

4.20 Site ID: GN3-90

Refer Slides to 47.

Level of risk unchanged since 2017.

Collapse occurred earlier in 2021 of part of the ledge below the lookout on Gnarabup Point. It should be noted that this hazard is closely associated with GN3-40 and the whole area below the lookout in this area is heavily eroded and people are traversing along the ledges below the lookout. Extensive measures to discourage public access, manage erosion and inform the public of risks are proposed for the whole of the area below the lookout. Refer specifically to Slides 43 to 47 for details.

It should be noted that whilst the risk levels have not increased since 2017, ongoing erosion and increased public access will see these levels increase. Reference to Slide 43, which utilises an October 2021 aerial image clearly shows the extent of eroded ground west and north or the lookout, ground that comprises weak friable limestone/sand. Measures are needed to prevent further erosion and limit public access within the hazard zone in order to stop the risk levels from increasing.

4.21 Site ID: GN3-100 (Gnarabup Beach Cave)

Refer Slides 42 and 48

Level of risk largely unchanged since 2017.

4.22 Site ID: GN5-5 (Stairs above White Elephant Beach Café)

Refer Slides 42, 49 and 50

These stairs were previously built upon a large overhang that was getting progressively eroded with the overhang increasing in depth. Remedial work was undertaken earlier in 2021 to underpin the overhang, thus prevent further weathering and erosion of the ground under the stairs, but also in doing so providing physical support to the stairs. As such the likelihood of the stairs collapsing has substantially decreased and the risk to users of the stairs from collapse is similarly reduced.

It is noted that there is some minor erosion caused by rainfall running off the shotcrete face (refer Slide 49). A Coir matt bolster appears has been placed at the interface of the shotcrete and ground surface to limit erosion.

4.23 Site ID: GN5-30

Refer Slides 42 and 51

Level of risk largely unchanged since 2017.

This feature is a narrow ledge of overhanging rock. The risk level from this feature is relatively low because the grassed area at the base of the slope below the overhang is not currently used by the café for customer seating. Should this lawned area be used for café seating in the future the level of risk would increase significantly, and consideration might need to be given to collapsing the overhanging ledge of rock.

It is recommended a small “Rockfall Hazard Area” sign be installed in the lawn area below the hazard

4.24 Site ID: GN5-100

Refer Slides 42 and 52

Level of risk unchanged since 2017.

4.25 Site ID: GR1-85

Refer Slides 53, 54 and 55

Level of risk unchanged since 2017.

It is recommended that the damaged fence fronting this hazard area be repaired and “Rockfall Hazard Area” signage be installed.

There is an unofficial path through the dune close to this hazard (refer Slide 55). It is recommended that brushwood matting be placed across this path to discourage pedestrian traffic and encourage the re-establishment of vegetation.

4.26 Site ID: GR2-10

Refer Slides 53 and 56

Level of risk unchanged since 2017.

We recommend the erection of a “Rockfall Hazard Area” sign on the beach in front of this hazard.

4.27 Site ID: GR2-20

Refer Slides 53, 57 and 58

Level of risk unchanged since 2017.

This hazard has a “Rockfall Hazard Area” sign quite close to the hazard itself. We recommend a further sign is erected on the beach in front of the hazardous overhanging rock outcrop. Because a major collapse of the overhanging outcrop could spill about 5 m onto the beach it is also recommended as a matter of priority that a fence be erected on the beach 6 m from the dune beach interface to discourage access into the hazard zone.

Surf schools have been observed use the beach directly in front of this rockfall hazard. It is also recommended that the surf schools be contacted and advised to locate themselves outside the hazard zone. Furthermore, it is recommended a seasonal (summer) fence be erected along the alignment shown on Slide 58. Such a summer fence (November to April 2022) would be in place when beach usage is higher. The fence could be removed during winter months when it is most likely to get washed out by large waves or the beach be eroded. It is noted that even during summer months the fence could be washed out or the beach eroded, for this reason it is recommended that the fence is a lost cost temporary fence and that part of the fence be secured well to a rock outcrop and the fence constructed such that the fence components do not get lost along the beach if it is uncut or damaged by waves (e.g. plastic star pickets secured to fence wire which is anchored to rock outcrop).

4.28 Site ID: GR3-1

Refer Slides 59 and 60.

This is a new location. Details of the hazard are described on Slide 60. The rockfall risk at this site is below the tolerable risk levels tabulated in Section 4.1.

A “Rockfall Hazard Area” sign should be added on the beach in front of the hazard. There is currently an informal pathway where people take a short cut across the dunes and rocks leading to this area. Revegetation of those parts on the path on dune should be undertaken to discourage pedestrian traffic directly into the hazard area.

4.29 Site ID: Wallcliffe

4.29.1 Overview

Refer Slides 61, 62 and 63.

Wallcliffe is an area of Aboriginal importance. It is a 20-30 m high vertical cliff fronting the Margaret River and has been described by Gordon (2012) as a doline wall. Doline is another term for a sinkhole and is often used specifically to describe sinkholes in a limestone rock sequence.

Wallcliffe is now closed to the public but has been used by rock climbers in the past. Several fixed climbing bolts and anchors across a number of climbing routes have been installed to facilitate sport climbing. We understand SAMR wish to tender a contract for the removal of these climbing anchors to preserve the character and heritage of this natural feature. An inspection was requested as part of the current Cliff Stability inspection of the Wallcliffe area to assess geological hazards which may have an impact on the removal of these climbing anchorage.

Karstic features associated with caves and dolines can be seen in the "wall" including a cave system "Wallcliffe Cave", a number of notch caves or galleries where the cliff forms substantial overhangs. At these locations stalactites can be seen. Smaller cave entrances at different levels on the cliff can be seen where the throats of the doline have been exposed when the river cut into the limestone hillside. There are numerous caves and overhangs within and along the cliff face, along with stalactites.

We noted during our inspection many bees and a large number (20+) of natural beehives hanging from the entrances to caves and from overhangs. In addition, we noted birds of prey nesting high on the cliff face.

We have not quantified a risk from rockfall like the other sites because this is dependent on both the activities being undertaken and the degree of exposure to the hazard. As the site is closed to the public there would be very few people visiting the site and as such the risk to individuals is considered low despite evidence of different sized blocks falling from the cliff from time to time.

Clearly a different set of risks can occur, if for instance the site was still used by climbers. For instance, the person belaying the climber being struck by a dislodged rock. These risks depend on controls put in place by the climbing groups but as Wallcliffe is currently closed, again this risk is considered low.

4.29.2 Hazards and Risks that Need Managing

There will be a number of geological hazards and related risks the contractor engaged to remove the climbing anchors will need to control.

Since 2019 the various informal paths in and around Wallcliffe have overgrown and the contractor will need to carefully plan activities, and plan to keep the number of times an access route needs to be trafficked to an absolute minimum in order to limit vegetation disturbance. Vegetation disturbance along the crest will increase the potential for future rain induced rockfalls from the cliff crest. Pedestrian pathways through shrub to access Wallcliffe will also need to be reinstated or covered in brush matting on completion of the anchor removal works to discourage future public access and minimise erosion.

Dislodgement of rocks and particularly stalactites is a risk that needs to be managed. Careful route planning will be required, and controls should be in place to ensure no personnel are directly below the cliff whilst a worker is above.

It is noted that there are overhangs on many of the climbing routes. A contractor deploying a technique of removing the anchors as he descends may have trouble in reaching some of the anchors under the overhangs. Also, with a top-down anchor removal methodology they would also end up at

the base of the cliff in the hazard zone and would then need to walk up to the crest disturbing vegetation before undertaking the next abseil descent.

An alternative removal technique might therefore be considered to reduce the rockfall risk. This would involve abseiling and attaching progressively to each existing anchor in the route until the lowermost anchor is reached. The lowermost anchor is then removed by grinding the bolt flush with the limestone surface and any residual climbers chalk marks washed from the face. Any works required to remove evidence of the bolt/climbing history (e.g., removal of rope or slings still on the face) needs to be undertaken at that time before ascending to the next anchor and repeating the process. Whilst this technique would involve rope ascent techniques, the advantage is easier access to the anchors below overhangs that require removal, which cannot be reached by simply abseiling. This methodology also avoids multiple base-of-cliff to crest-of-cliff walks that will inevitably result in extensive vegetation damage, and such pathways will take a long time to become overgrown again.

There are also other hazards to manage, e.g. Bees and the contractor will need to prepare a detailed health and safety management and environmental plan that manages the health and safety risks of their own personnel, but also minimises environmental and ecological damage to the cliff and the vegetation and fauna in the immediate vicinity. Whilst there are several potential hazardous features such as stalactites that could fall if disturbed, adequate pre-planning should mean that the most hazardous features are avoided and ideally rocks, and stalactites are not detached. However, in the event they were detached, a well-planned operation would ensure that no people are ever in the line of fire, and as such safety risks are managed.

5 SIGN AUDIT

Appendix C shows photos of relevant signs, noting the likely shire ID, and locations for sign repair, replacement and improvement is required. Approximate co-ordinates are provided for locations for proposed new signs. The exact locations will need to be determined on site at the time the sign is erected to ensure the sign is not too close to the hazard zone and has good visibility to people approaching the hazard zone, before they enter the hazard zone. Some guidance is provided for specific locations in the Site Observations and Photographs appendix to this report, Appendix A.

It should be noted sign locations on beaches need to be assessed prior to erecting signs to ensure the location of the post is not likely to be undercut by beach erosion.

6 FUTURE MONITORING REQUIREMENTS

Risks can change. A major storm causing coastal erosion, heavy rain infiltrating tension cracks or a bushfire affecting coastal vegetation are all events that can result in a greater potential for rockfall.

It is recommended that Shire personnel inspect the sites described in this report following major storms, bushfire or following reports of changed conditions from the public and if there is evidence of greater erosion engage a geotechnical professional to assess the new level risk and make recommendation to mitigate or manage the risk as required.

Over and above undertaking inspection following such exceptional events the following future monitoring regime is recommended:

Inspection every year (during Spring) at the following locations:

GC3-50, PR4-30, PR4-100, PR6-85 (Whole of Riflebutts Cliff area), GN3-40/GN3-90 (area below Gnarabup Lookout area), GR2-20 and GR3-1.

These are locations where the November 2021 level of risk is between 4.0 and 9.9 $X10^{-6}$.

Every two years (during Spring) it is recommended all areas documented in this report are re-inspected.

As part of both the annual and biennial inspections a Quantitative Risk Assessment should be undertaken to assess the if risk levels have changed. The inspection should also include observations of factors and events that might lead to an increase rockfall risk in the future, if not rectified. Such observations and events might be factors such as coastal erosion leading to cliff undercutting, new informal pathways where people are accessing a hazard zone, perhaps as a short cut, or increased erosion due to vegetation disturbance (e.g. from informal pathways, bushfire etc.).

7 REFERENCES

AGS (2007), *Practice Note Guidelines for Landslide Risk Management 2007*. Australian Geomechanics, Vol 42, No 1, March 2007

Gordon, F. R. (20212). *Geology of Quaternary Coastal Limestones of Western Australia*. Doctor of Philosophy, Department of Applied Geology, Curtin University, September 2021.

8 CLOSURE

The findings contained within this report are the result of site observations, judgement of likelihood and impact of slope and cliff hazards and risk assessment conducted in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site. Conditions change with time and following severe weather events.

The information presented in this report therefore represents the condition observed and risk assessed at the time of the site inspection and from time-to-time additional surveys will be required to update observed conditions in accordance with the guidance provided in this report.

This report has been prepared for use by Shire of Augusta Margaret River in relation to managing coastal cliff stability risk at a number of discrete locations in accordance with generally accepted consulting practice. No other warranty, expressed or implied, is made as to the professional advice included in this report. Use of this report by parties other than Shire of Augusta Margaret River and their respective consultants and contractors is at their risk as it may not contain sufficient information for any other purposes.

For and on behalf of
CMW Geosciences Pty Ltd

Prepared By:

Amy Tsagopoulos
Senior Engineering Geologist

Reviewed By:

Matthew Tutton
Senior Principal Geotechnical Engineer/ Engineering Geologist

Distribution: 1 copy to Shire of Augusta Margaret River (electronic)
Original held by CMW Geosciences Pty Ltd

Appendix A

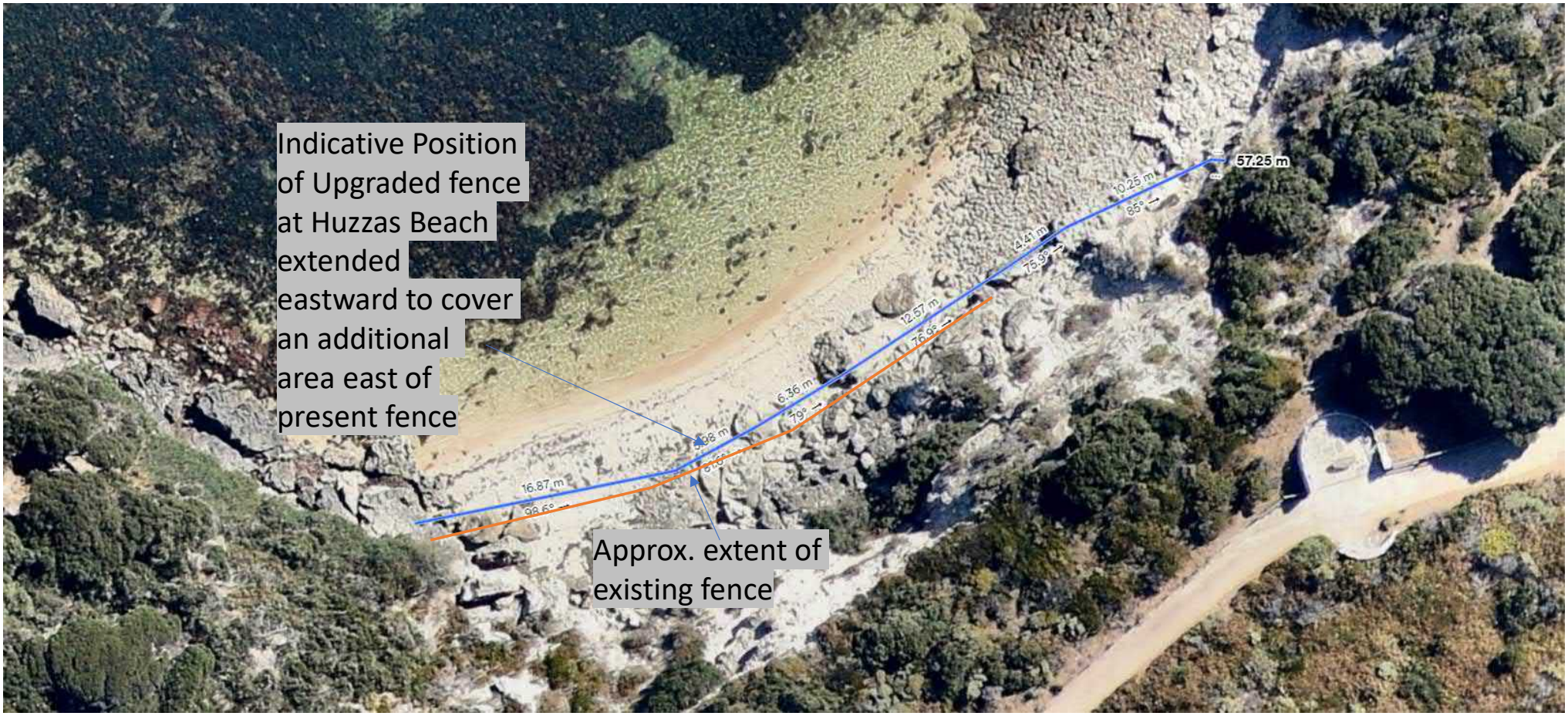
Site Observations and Photographs

Gracetown GC3-50 and GC4-60

Gracetown GC3-50

Improve fencing including extending eastwards to prevent access to area of recent coastal erosion and moving further away from hazard (refer Slide 3). Add a 'Rockfall hazard sign' also include information signson approaches to Huzzas cliff from both directions (refer Slide 4 for approximate positions)

Cliff overhang – Level of Risk to Individual Most at Risk (R_{DI}) increased due to coastal erosion at east end of Huzzas Cliff
Nov 2021 $R_{DI} = 4.3 \times 10^{-6}$


Indicative Position of Upgraded fence at Huzzas Beach extended eastward to cover an additional area east of present fence
Approx. extent of existing fence
57.25 m
10.25 m
85°
4.41 m
75.9°
12.57 m
75.6°
6.36 m
79°
16.87 m

Gracetown GC3-50

Gracetown GC4-60

Side view of overhang (Huzzas Beach/Cliff in background)

Level of Risk to Individual Most at Risk (R_{DI}) remains the same as previous assessment – Nov 2021 R_{DI} = 6.1×10^{-7}

Gracetown GC5-75, GC6-15, GC6-50 and GC6-60

Gracetown GC5-75

Recommend that brushwood is placed at these locations to encourage vegetation regrowth and discourage people climbing or descending the slope creating further erosion and putting themselves in the hazard area

Remedial works (removal of overhang) occurred in May 2020, subsequently the Level of Risk to Individual Most at Risk (R_{DI}) has reduced to 1.2×10^{-7}

Gracetown (Southpoint Carpark) Stairs

Minor coastal erosion occurring. Place brushwood on parts of slope where vegetation has been impacted. Monitor situation on beach, place riprap or other beach erosion control measures as and when required and extend stanchion to stairs if they become undercut.

Gracetown GC6-15

Main hazard (this block pulling away and rolling down slope

Note since 2017 Golder inspection the Lookout that sat onto of a potentially unstable block was removed. Steps are down sufficient distance back not to be impacted by this hazard

Level of Risk to Individual Most at Risk (R_{DI}) is now relates to a person traversing the rocky foreshore below the hazard rather than the steps above the hazard $R_{DI} = 2.9 \times 10^{-6}$

Gracetown GC6-50

Main Hazard

New location

If rockfall was to occur, it is not expected to reach the beach due to vegetation and other boulders breaking its fall. If it topples, it is likely to fragment into small pieces. Risk is assessed to be relatively low R_{DI} =8.6 x10 $^{-7}$

Recommend additional sign.

Gracetown GC6-60

No apparent retrogression of embankment to west of GC6-60 since 2019. Further establishment of native vegetation has occurred which is helping to maintain status quo (see photo on right)

Gracetown GC6-60

Fracture from August 2019

November 2021 inspection indicates negligible change to tension crack from 2019

Level of Risk to Individual Most at Risk (R_{DI}) Nov 2021 = 9.75×10^{-7}

Gracetown GC6-60

Rockfall debris still present on wave cut platform similar to 2019. Rounded boulders and cobbles indicative of high wave energy

Gracetown GC6-100

Gracetown GC6-100

Level of Risk to Individual Most at Risk (R_{DI}) not changed since previous assessment – Nov 2021

$R_{DI} = 8 \times 10^{-7}$

Prevelly PR3-165 and PR4-30

Prevelly PR3-165

Risk to Individual Most at Risk (R_{DI}) not changed since previous assessment (2017)

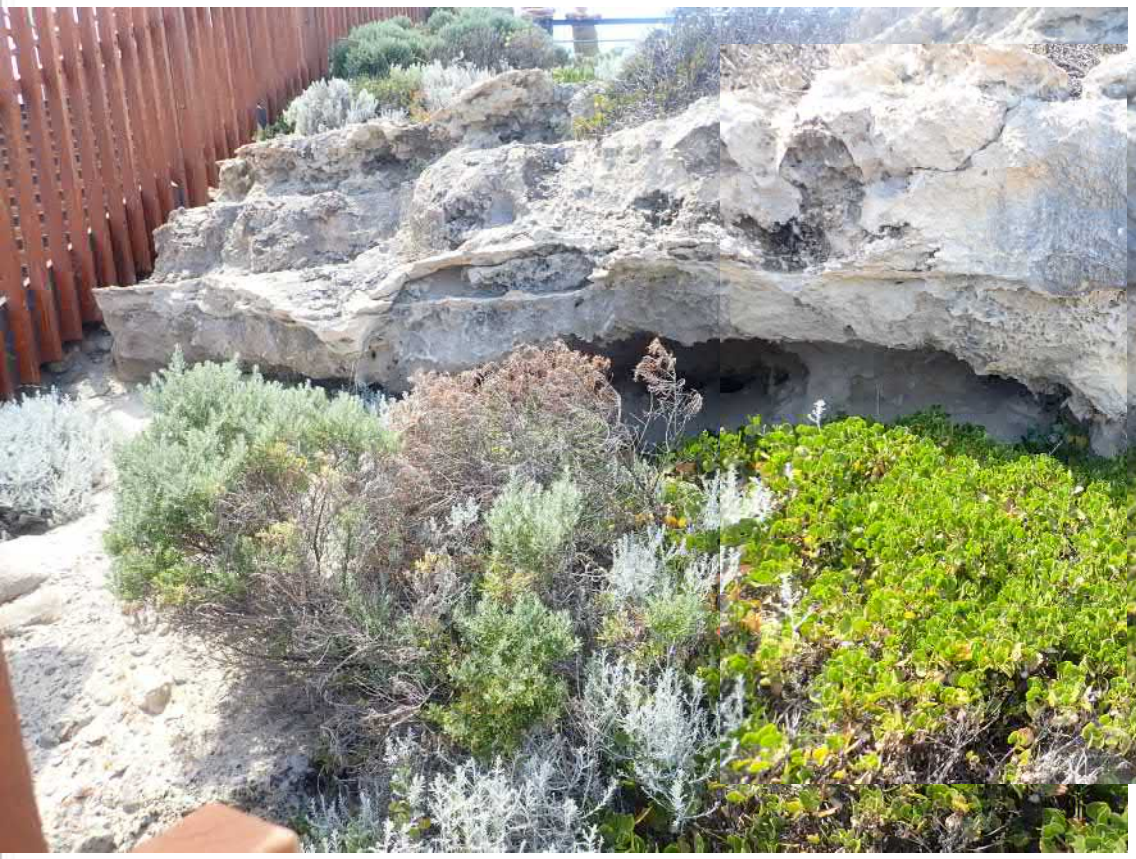
$R_{DI} = 1.5 \times 10^{-6}$

Prevelly PR3-165

Overhang has not changed since previous inspection

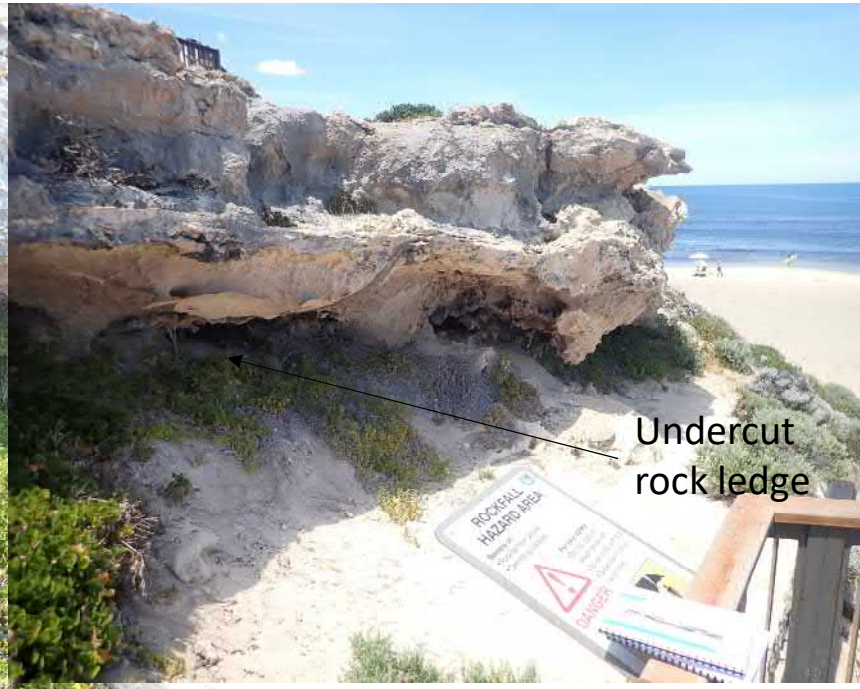
Prevelly PR4-30

Prevally PR4-30

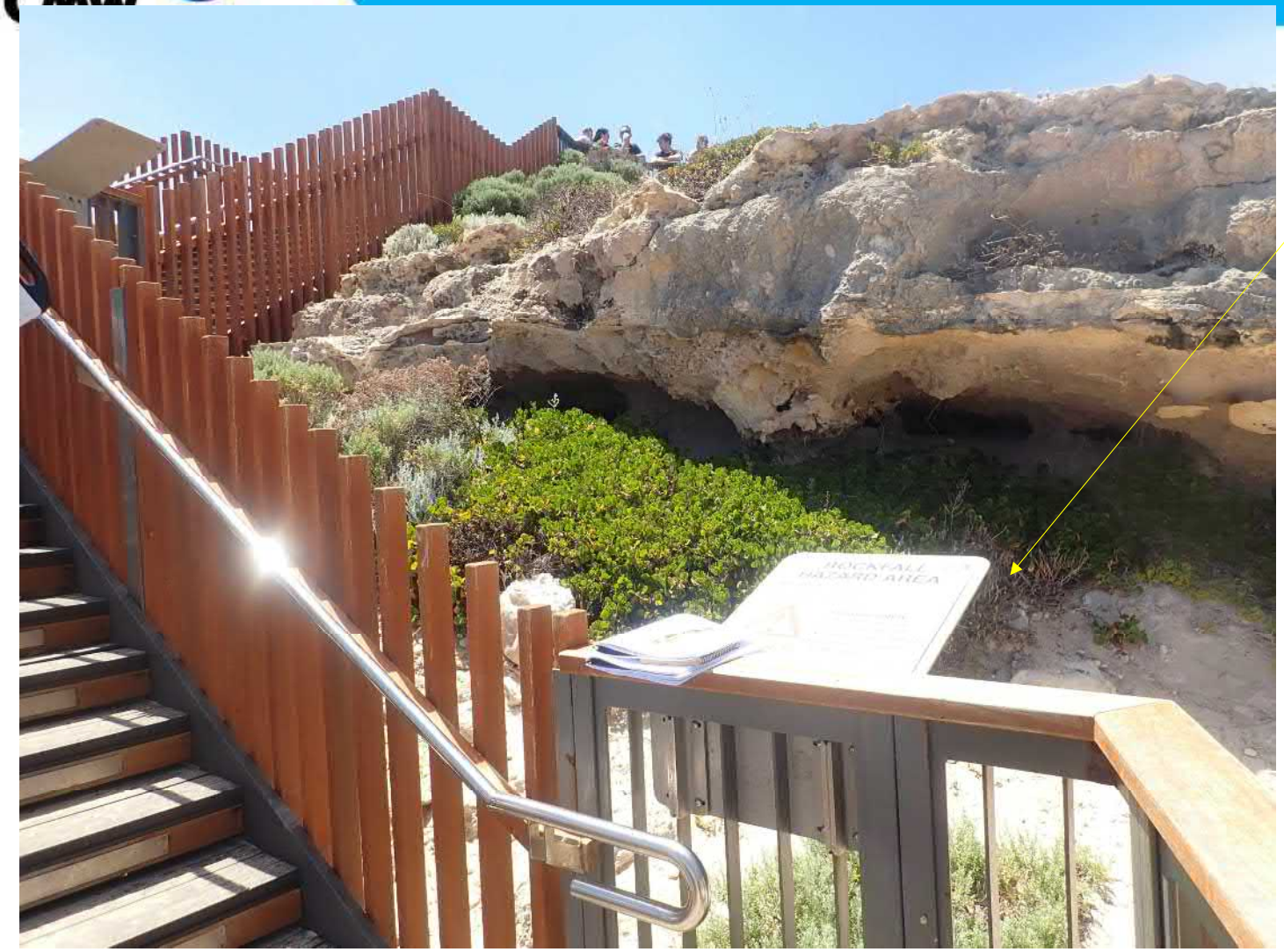


Vegetation cover in front of rock ledge and protecting the ledge from wind erosion is similar to the previous (2019) inspection.

Main Risk would be to people sitting on top of this rock ledge if it was collapse



Prevelly PR4-30



Bench and lookout has been removed since 2017 inspection removing a major element at risk. Sign has been put in place. Main risk is now to people sitting on rock ledge above (e.g. spectating during surf events).

Risk to Individual Most at Risk (R_{DI}) sitting on top of rock ledge as spectator has been assessed as $R_{DI} = 2.9 \times 10^{-6}$

Prevelly PR4-40

Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2017)

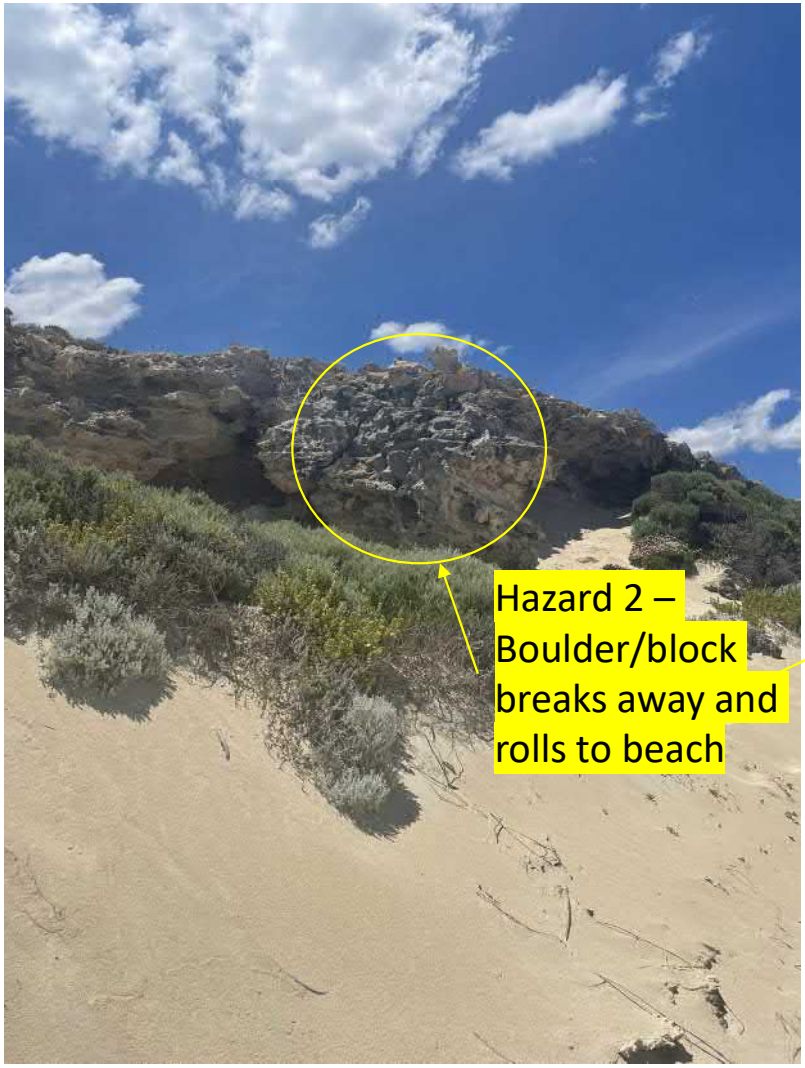
$R_{DI} = 1.2 \times 10^{-6}$

Good stand-off distance between hazard and fence.

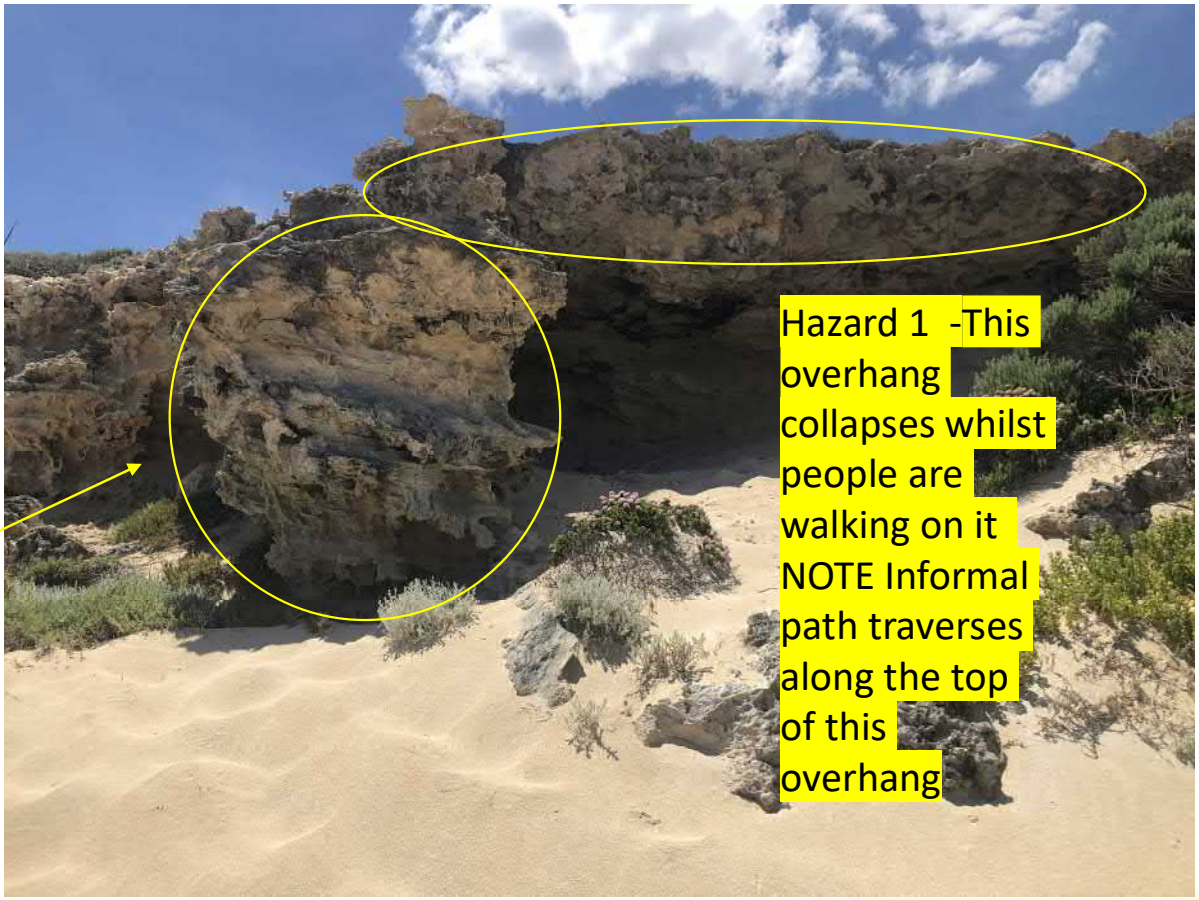
Sign in good condition.

Prevelly PR4-100, PR5-50 & PR5-150

Prevelly PR4-100



Risk to individual most at risk has been re-assessed and has increased.



Prevelly PR4-100

Risk to Individual Most at Risk (R_{DI}) has <u>increased</u> since previous assessment (2017) $R_{DI} = 4.8 \times 10^{-6}$ This is due to increased erosion and pedestrian traffic in hazard zone

Evidence of pedestrian traffic, including along the overhang (in previous slide). Recommend measure to discourage pedestrian traffic e.g. Improve signage (existing sign is too small) and the provision of brushwood on the existing informal tracks between the picnic area and the hazard and beyond. The fence in the photo above could include a mesh fence panel to stop people ducking under it.

Prevelly PR5-50

Site conditions similar to previous assessment.

Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2017)
$R_{DI} = 1.8 \times 10^{-6}$

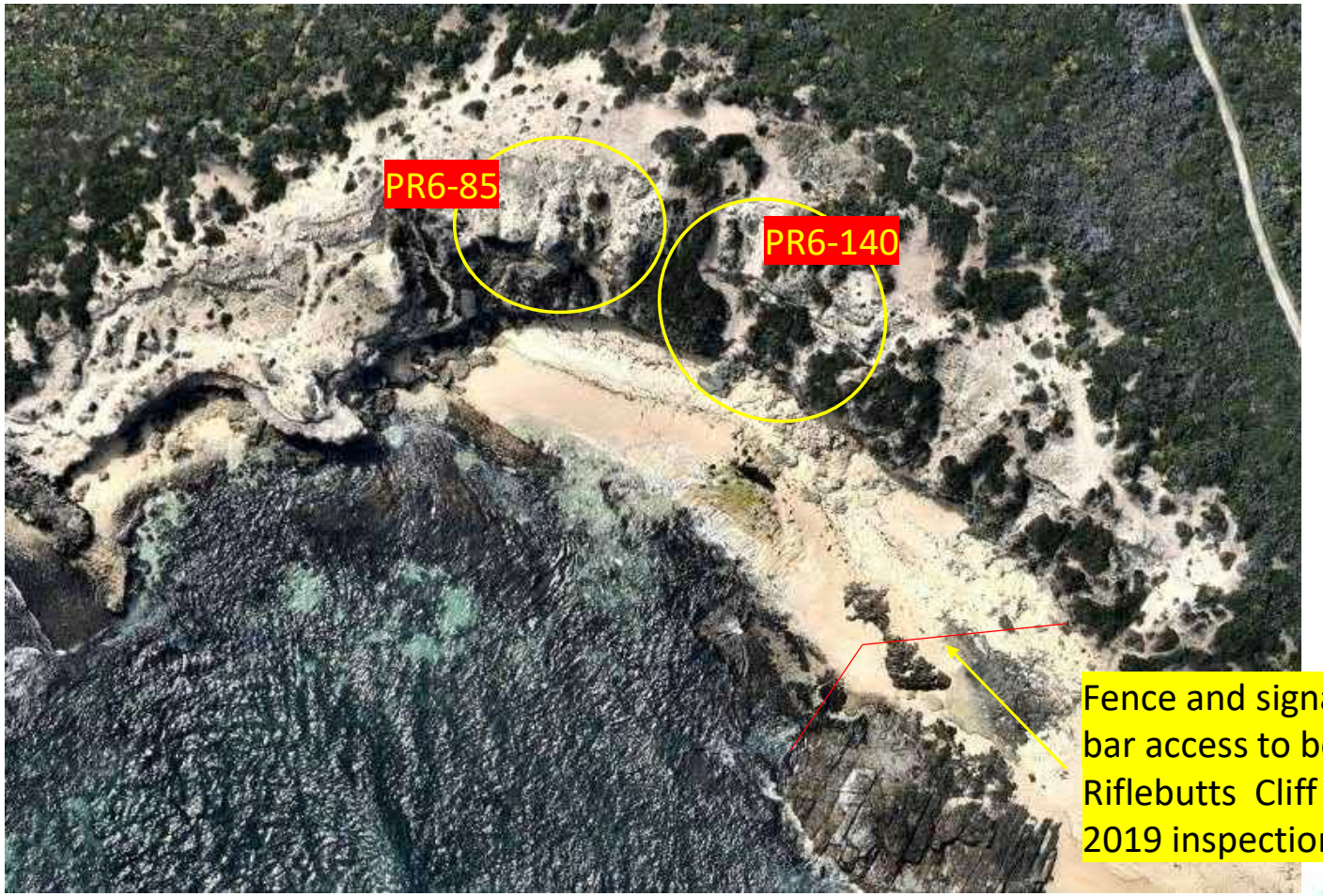
Add rockfall hazard sign 5 m from hazard at edge of beach.

Prevelly PR5-150

Site conditions similar to previous assessment. Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2017)

$R_{DI} = 1.5 \times 10^{-6}$

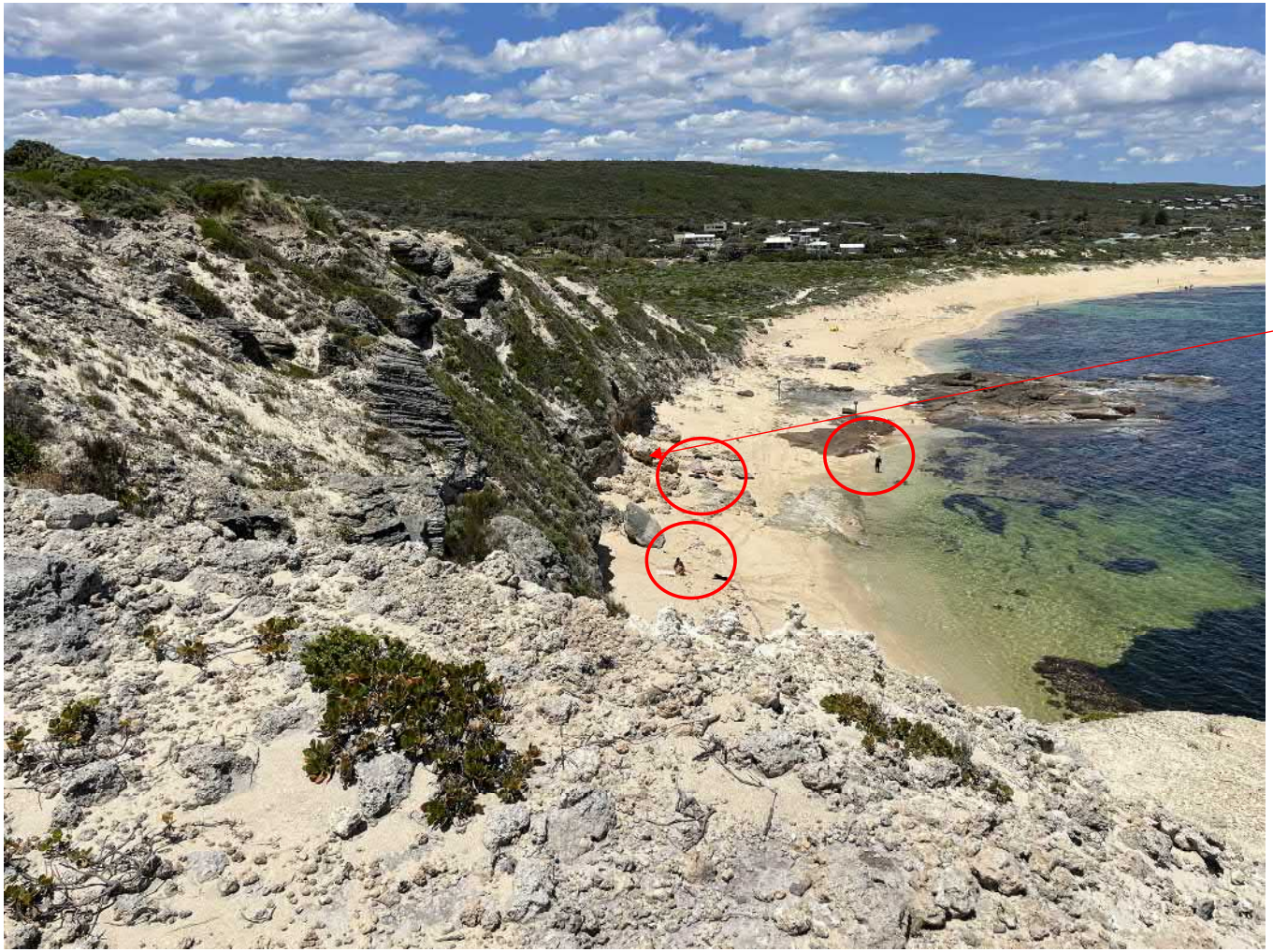
Prevelly PR6-85 & PR6-140 (Riflebutts Beach)



Prevally PR6-85 & PR6-140

Conditions at top of PR6-85 and PR6-140.

Prevelly PR6-85 & PR6-140



Three sets of recreational users (5 people) who have crossed the fence to access the beach.

Recent rockfall approx. 15 m^3 (August 2021) with a recreational user sitting directly in front of the rockfall.

Prevelly PR6-85

Recreational user in fenced off area

Prevelly PR6-85 & PR6-140

Fencing in place to with signage to limit access and use of beach by recreational users.

Prevelly PR6-85 & PR6-140

Appropriate signage warning of rockfall hazard in place and in good condition at southern end of Riflebutts Beach Hazard Zone.

Prevelly PR6-140

This sign is now redundant and should be removed

Prevelly PR6-140

Scar of rockfall of August 2021.

The landslide was estimated to be about 15 m^3 and run out about 8 m onto the beach. The larger pieces of debris remain but much of the smaller sized debris has been removed by wave action.

Risk to Individual Most at Risk (R_{DI}) assessed to be relatively low in this area but only due to people not accessing the beach due to the fence and signage November 2021 $R_{DI} = 2.2 \times 10^{-6}$

Prevelly PR6-85

Historic Rockfall debris resting on steep slope and at base of cliff.

Prevelly PR6-85

Prevelly PR6-85

Recent cobble fall.

A4 clipboard for scale

Gnarabup – GN1-25 & GN1-50

Gnarabup – GN1-25

Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2017)

$R_{DI} = 9.6 \times 10^{-8}$

Vegetation and shallow gradients in front of hazard reduce likelihood of rockfall reaching beach

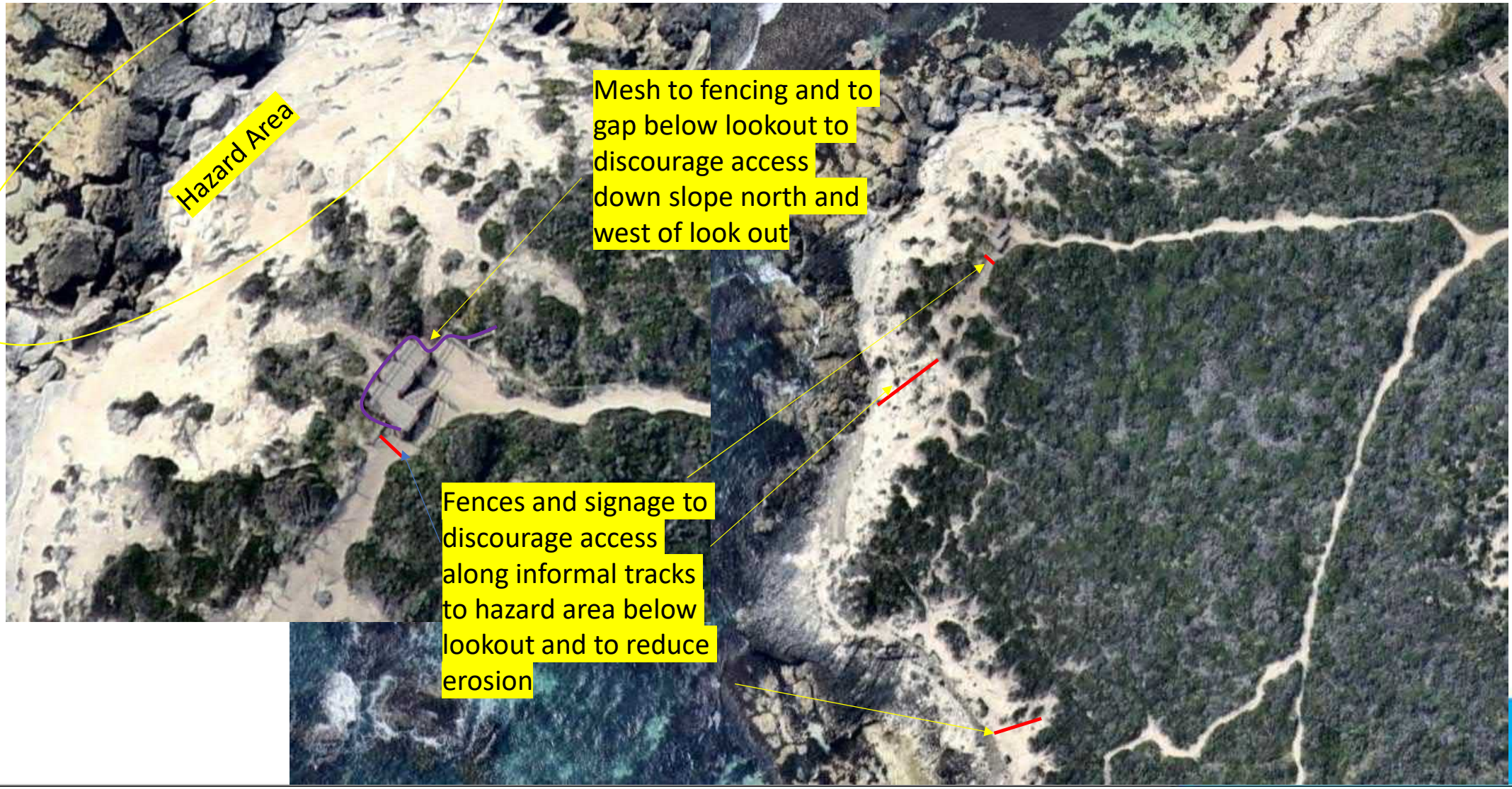
Gnarabup – GN1-50

Risk to Individual Most at Risk (R_{DI}) has not changed since previous assessment (2017) $R_{DI} = 2.0 \times 10^{-7}$

Add rockfall hazard area signs be erected on beach to be viewed when approaching the hazard from both the north and the south..

Gnarabup – GN3-90, GN3-40, GN5-5, GN5-30 and GN5-100

Gnarabup – GN3-90, GN3-40, GN5-5, GN5-30 and GN5-100



Gnarabup – GN3-90

Add mesh to restrict access.

Add brushwood and/or revegetate to discourage informal pedestrian access and promote vegetation growth

Gnarabup – GN3-90

Heavily trafficked. Improve fencing to restrict access.

Gnarabup – GN3-40 and GN3-90

Risk to Individual Most at Risk (R_{DI}) = 4.6 x 10^{-6} and 1.5 x 10^{-6} for GN3-40 and GN3-90 respectively. Ongoing erosion is likely to see these risk levels increase. Measures are needed to prevent further erosion and to discourage public access to the ledge below the lookout.

Temporary sign and fence present following collapse earlier in 2021.

The sign and fence should be made permanent with a sign stating 'Imminent Rockfall Risk Beyond this point" other fences and signs as illustrated on Slide 43 are also recommended

Gnarabup – GN3-90

Improve temporary fencing and signing to permanent. Discourage pedestrian traffic. Some access appears to occur down the slope from the lookout. Other people access along the ledge from the south traffic.

Gnarabup – GN3-100

The Gnarabup Beach Cave The level of Risk to the Individual Most at Risk (R_{DI}) remain similar to 2017 at 8.3 x 10^{-7}

Gnarabup – GN5-5

The risk level has reduced due to control/remedial measures put in place in 2021 to reduce weathering under the overhang and to underpin the stairs. Risk to the Individual Most at Risk assessed to be 2.3 x10 $^{-7}$

Gnarabup – GN5-5

Pins previously installed approximately 101mm apart (previous visit 100mm separation).
Continue to monitor creep.

Continue to monitor undercutting.

Gnarabup – GN5-30

The level of Risk to the Individual Most at Risk (R_{DI}) remains similar to the 2017 assessment.

$R_{DI} = 2.3 \times 10^{-7}$

Add Rockfall Hazard sign in lawn area at base of this feature.

Note there is Minimal traffic in this area and the grassed area below is not used by the Café for customers. The level of risk would increase significantly if this area was used for seating

Gnarabup – GN5-100

The level of risk to the Individual Most at Risk (R_{DI}) remains the same as in 2017. November 2021 $R_{DI} = 7.6 \times 10^{-7}$

Grunters – GR2-20, GR2-10 & GR1-85

Grunters – GR1-85

The level of Risk to the Individual Most at Risk (R_{DI}) remains the same as the 2017 assessment.

$R_{DI} = 7.8 \times 10^{-8}$
Repair fence and install rockfall hazard area signage.

Broken fence.

Grunters – GR1-85

Re-vegetate or place brushwood matting across unofficial access track to discourage traffic.

Grunters – GR2-10

The level of Risk to the Individual Most at Risk (R_{DI}) remains the same as the 2017 assessment.

$R_{DI} = 1.3 \times 10^{-7}$

Add ‘rockfall hazard area’ sign on the beach.

Grunters – GR2-20

Approximately 3m overhang

Add rockfall hazard sign on the beach as well as temporary fencing (Nov to April_ on beach 6 m from dune beach interface.

The level of Risk to the Individual Most at Risk (R_{DI}) remains the same as the 2017 assessment.

$R_{DI} = 6.2 \times 10^{-6}$


GR2-20
47.12 m
19.3°
4.57 m
7.61 m
337.7°
8.16 m
340°
10.38 m
331.4°
9.33 m
326.2°
7.06 m
271.1°
Approx. extent of temporary summer fence 6 m off Feb 2022 vegetation line

Grunters – GR3-1

Grunters – GR3-1 (New location since 2017 inspection)

Area approximately 10m wide with a 2.5m overhang.
Recommend adding a rockfall risk sign at the base and re-vegetating informal pathway across rocks leading to this area to discourage pedestrian traffic.

The level of Risk to the Individual Most at Risk (R_{DI}) = R_{DI} = 6.2 x 10^{-6}

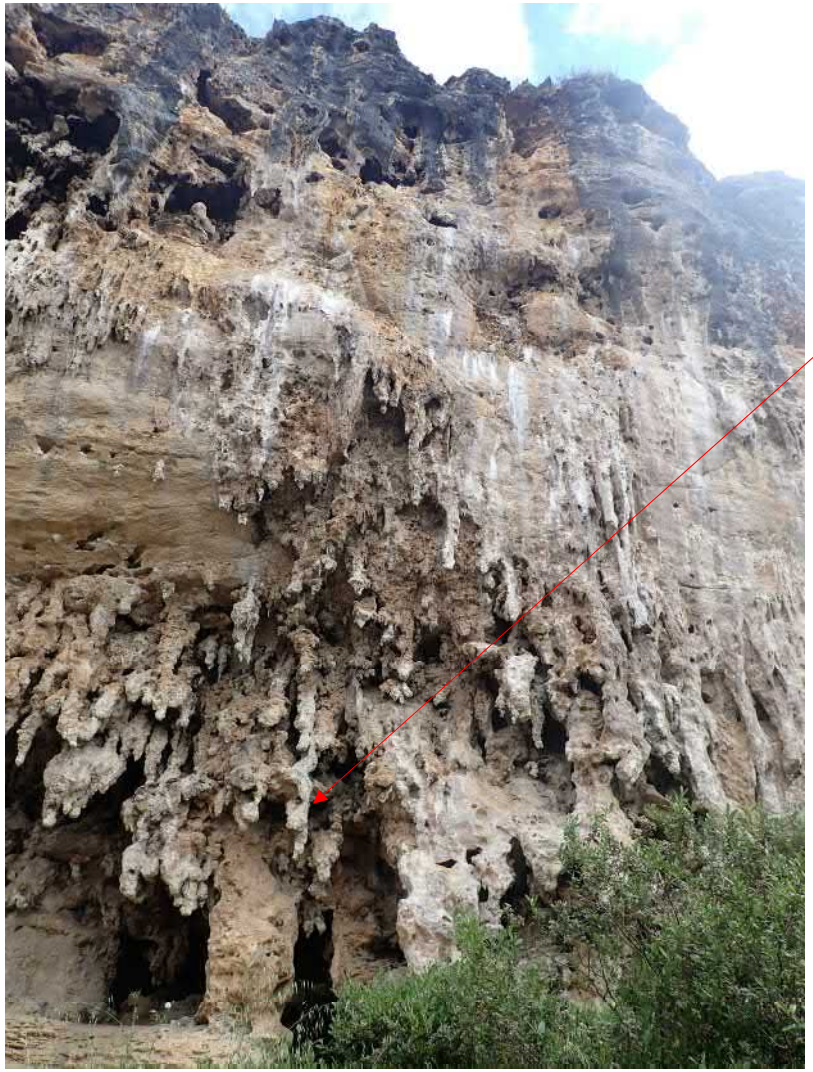
Wallcliffe

View of Wallcliffe, surrounded by dense vegetation. Care should be taken to preserve vegetation whilst undertaking climbing bolt removal

Wallcliffe

Caves within Wallcliffe cliff face - there are many wild bee hives within the cliff presenting hazard to contractor employer to remove climbing bolts

Wallcliffe



Stalactites potentially can drop process pf removing climbing Keeping people out of the potential drop zone will manage the safety risk but a methodology that avoids descending on ropes into this stalactite zone would help also preserve these features from damage as well as manage safety risk

Appendix B
Risk Assessment

Location	Gracetown						
Hazard ID	**GC3-50**	**GC4-60**	**GC5-75**	**GC6-15**	**GC6-50**	**GC6-60**	**GC6-100**
Recommendaed mitigation	**upgrade, extend and realign fence, informatiive signage, rockfall signage**				**Install rockfall hazard sign**		
Comments			Mitigation works conducted in 2020		New location		
Main Hazard Type Assessed	Rockfall	Rockfall	Rockfall	Rockfall	Rockfall	Rockfall	Rockfall
Risk scenario	People traversing narrow beach in front of Shire part of GC3-50	People traversing beach in front of hazard	People exiting stairs onto beach	Lookout removed so risk is no longer to lookout/stairs but to people traversing beach	People traversing rocky foreshore	People traversing rocky foreshore	People traversing beach
R_{DI} (without risk mitigation recommneded)	4.3E-06	6.1E-07	1.2E-07	2.9E-06	8.6E-07	9.75E-07	8.0E-07
$P_{(H)}$	1.0E-01	1.0E-01	1.0E-02	6.7E-02	1.0E-01	1.00E-01	5.0E-02
$P_{(S:H)}$	5.0E-01	2.9E-02	5.5E-02	5.0E-01	1.0E-01	1.14E-01	7.4E-02
$P_{(T:S)}$	1.1E-05	2.9E-05	2.9E-05	1.1E-05	1.1E-05	1.14E-05	2.9E-05
$V_{(D:T)}$	0.5	0.5	0.5	0.5	0.5	0.5	0.5
N	15	15	15	15	15	15	15
R_{SOC}	2.9E-06	4.1E-07	7.8E-08	1.90259E-06	5.70776E-07	6.50E-07	5.3E-07
R_{LOL}	2.9E-07	4.1E-08	7.8E-09	1.90259E-07	5.70776E-08	6.50E-08	5.3E-08
Total individual visitors at any one time	10	10	10	10	10	10	10
R_{CI}	2.88E-03	4.08E-04	3.90E-04	9.51E-04	2.85E-04	3.25E-04	2.66E-04
N_T - total number of individuals visiting the site each year (assuming no repeat visits)	10000	10000	50000	5000	5000	5000	5000
Total individual visitors per day in a year	27	27	137	14	14	14	14
Risk Variable breakdown							
P_H							
Return Interval for Rockfall (once every ? Yrs)	10	10	100	15	10	10	20
$P_{S:H}$							
Length of Trajectory where people could be impacted (m) if rockfall is main hazard	12	10	10	20	10	12	12
Width of block (m)	18.0	4.0	5.0	4.0	1.5	15.0	10.0
Potential Impact area (m^2)	216	40	50	80	15	180	120
% of Trajectory where humans could be impacted that gets hit by rockfall or affected by collapse	70%	50%	50%	50%	20%	50%	50%
Assumed Spatial Impact Area (m^2)	151.2	20	25	20	3	90	60
Approximate general area in front of hazard a proportion of which will be in the impact area (m^2)	300	700	457	40	30	790	806
P_{TS}							
Minutes per year	525600	525600	525600	525600	525600	525600	525600
% significant rockfall in Rain	80%	80%	80%	80%	80%	80%	80%
% significant rockfall in Dry	20%	20%	20%	20%	20%	20%	20%
Time Spent in Rockfall Hazard Zone if raining (min)	5	5	5	5	5	5	5
Time spent in Rockfall Hazard Zone if dry (min)	10	55	55	10	10	10	55

Location	Gracetown						
Hazard ID	**GC3-50**	**GC4-60**	**GC5-75**	**GC6-15**	**GC6-50**	**GC6-60**	**GC6-100**
Weighted Time exposed in rain (min)	4	4	4	4	4	4	4
Weighted Time exposed in dry (min)	2	11	11	2	2	2	11
Total Weighted Time exposed to Rockfall (min)	6	15	15	6	6	6	15

Location	Prevelly							
Hazard ID	**PR3-165**	**PR4-30**	**PR4-40**	**PR4-100**	**PR4-100**	**PR5-50**	**PR5-150**	**PR6-85**
Recommendaed mitigation		**security to prevent access during surf competititons**		**additional signage**				
Comments								Access reduced due to fence
Main Hazard Type Assessed	Rockfall	Collapse	Rockfall	Collapse	Rockfall/collapse	Rockfall/Collapse	Rockfall/Collapse	Rockfall
Risk scenario	People traversing beach or sunbathing	People jumping fence to sit on top of rock ledge during surf competition	People traversing beach or sunbathing	People traversing overhang as it collapses	Collapsing overhang rolls down to beach	Collapsing overhang rolls down to beach	Collapsing overhang rolls down to beach	Dog walker/sunbathers impacted by large falling block
R_{DI} (without risk mitigation recommneded)	1.5E-06	2.9E-06	1.2E-06	3.1E-06	4.8E-06	1.8E-06	1.5E-06	6.1E-06
$P_{(H)}$	1.0E-01	1.0E-01	5.0E-02	1.0E-01	1.0E-01	5.0E-02	5.0E-02	2.0E-01
$P_{(S:H)}$	6.8E-02	1.0E+00	1.2E-01	1.0E+00	2.3E-01	1.7E-01	1.4E-01	1.5E-01
$P_{(T:S)}$	2.9E-05	1.4E-04	2.9E-05	4.2E-06	2.9E-05	2.9E-05	2.9E-05	1.7E-05
$V_{(D:T)}$	0.5	0.1	0.5	0.5	0.5	0.5	0.5	0.8
N	15	2	15	15	15	15	15	15
R_{SOC}	9.7E-07	7.1E-06	8.3E-07	4.2E-07	3.2E-06	1.2E-06	1.0E-06	1.6E-06
R_{LOL}	9.7E-08	1.4E-06	8.3E-08	2.1E-07	3.2E-07	1.2E-07	1.0E-07	4.0E-07
Total individual visitors at any one time	10	5	10	2	10	10	10	4
R_{CI}	1.46E-03	7.13E-05	8.30E-04	1.05E-03	1.61E-03	2.97E-04	2.55E-04	8.08E-04
N_T - total number of individuals visiting the site each year (assuming no repeat visits)	15000	50	10000	5000	5000	2500	2500	2000
Total individual visitors per day in a year	41	0	27	14	14	7	7	5
Risk Variable breakdown								
P_H								
Return Interval for Rockfall (once every ? Yrs)	10	10	20	10	10	20	20	5
$P_{S:H}$								
Length of Trajectory where people could be impacted (m) if rockfall is main hazard	16	5	5	NA	2	NA	NA	12
Width of block (m)	3.0	6.0	2.0	NA	1.5	NA	NA	10.0
Potential Impact area (m^2)	48	30	10	NA	3	NA	NA	120
% of Trajectory where humans could be impacted that gets hit by rockfall or affected by collapse	75%	100%	100%	100%	60%	NA	NA	60%
Assumed Spatial Impact Area (m^2)	36	30	10	5	1.8	10	10	72
Approximate general area in front of hazard a proportion of which will be in the impact area (m^2)	529	30	86	5	8	60	70	488
P_{TS}								
Minutes per year	525600	525600	525600	525600	525600	525600	525600	525600
% significant rockfall in Rain	80%	80%	80%	80%	80%	80%	80%	80%
% significant rockfall in Dry	20%	20%	20%	20%	20%	20%	20%	20%
Time Spent in Rockfall Hazard Zone if raining (min)	5	25	5	2	5	5	5	5
Time spent in Rockfall Hazard Zone if dry (min)	55	275	55	3	55	55	55	25

Location	Prevelly							
Hazard ID	**PR3-165**	**PR4-30**	**PR4-40**	**PR4-100**	**PR4-100**	**PR5-50**	**PR5-150**	**PR6-85**
Weighted Time exposed in rain (min)	4	20	4	2	4	4	4	4
Weighted Time exposed in dry (min)	11	55	11	1	11	11	11	5
Total Weighted Time exposed to Rockfall (min)	15	75	15	2	15	15	15	9

Location		Gnarabup						
Hazard ID	**PR6-140**	**GN1-25**	**GN1-50**	**GN3-40**	**GN3-90**	**GN3-100**	**GN5-5**	**GN5-30**
Recommendaed mitigation			**new rockfall signage**	**various sections of fencing**	**various sections of fencing**			**new rockfall sign**
Comments	Access reduced due to fence					Stairs underpinned in 2021		
Main Hazard Type Assessed	Rockfall	Rockfall	Rockfall	Collapse	Collapse	Collapse	Collapse	Rockfall
Risk scenario	Dog walkers/sunbathers	Sunbathers	Sunbathers	Walking on ledge below lookout	Walking on ledge below lookout	Small rockfall collapse onto people visiting cave	Collapse of stairs	Collapse of ledge onto people below
R_{DI} (without risk mitigation recommneded)	2.2E-06	9.6E-08	2.0E-07	4.6E-06	1.5E-06	8.3E-07	2.3E-07	2.6E-06
$P_{(H)}$	2.0E-01	5.0E-02	5.0E-02	1.0E-01	1.0E-01	1.0E+00	1.0E-02	2.0E-01
$P_{(S:H)}$	5.4E-02	9.0E-03	1.9E-02	2.1E-01	7.1E-02	9.1E-02	1.0E+00	1.5E-01
$P_{(T:S)}$	1.7E-05	2.9E-05	2.9E-05	2.9E-05	2.9E-05	3.0E-06	3.0E-06	2.9E-05
$V_{(D:T)}$	0.8	0.5	0.5	0.5	0.5	0.2	0.5	0.5
N	15	15	15	15	15	15	15	6
R_{SOC}	6.0E-07	6.4E-08	1.3E-07	3.1E-06	1.0E-06	5.5E-07	1.5E-07	4.3E-06
R_{LOL}	1.5E-07	6.4E-09	1.3E-08	3.1E-07	1.0E-07	5.5E-08	1.5E-08	4.3E-07
Total individual visitors at any one time	4	10	10	10	10	10	10	10
R_{CI}	2.98E-04	6.42E-05	1.32E-04	7.64E-04	2.54E-04	5.53E-04	1.33E-03	8.56E-05
N_T - total number of individuals visiting the site each year (assuming no repeat visits)	2000	10000	10000	2500	2500	10000	87600	200
Total individual visitors per day in a year	5	27	27	7	7	27	240	1
Risk Variable breakdown								
P_H								
Return Interval for Rockfall (once every ? Yrs)	5	20	20	10	10	1	100	5
$P_{S:H}$								
Length of Trajectory where people could be impacted (m) if rockfall is main hazard	16	10	10	NA	NA	6	NA	5
Width of block (m)	4.0	3.0	1.0	NA	NA	0.5	NA	3.0
Potential Impact area (m^2)	64	30	10	NA	NA	3	NA	15
% of Trajectory where humans could be impacted that gets hit by rockfall or affected by collapse	60%	25%	80%	NA	NA	100%	NA	50%
Assumed Spatial Impact Area (m^2)	38.4	7.5	8	15	15	3	10	7.5
Approximate general area in front of hazard a proportion of which will be in the impact area (m^2)	707	833	432	70	211	33	10	50
P_{TS}								
Minutes per year	525600	525600	525600	525600	525600	525600	525600	525600
% significant rockfall in Rain	80%	80%	80%	80%	80%	80%	80%	80%
% significant rockfall in Dry	20%	20%	20%	20%	20%	20%	20%	20%
Time Spent in Rockfall Hazard Zone if raining (min)	5	5	5	5	5	1	1	5
Time spent in Rockfall Hazard Zone if dry (min)	25	55	55	55	55	4	4	55

Location		Gnarabup						
Hazard ID	**PR6-140**	**GN1-25**	**GN1-50**	**GN3-40**	**GN3-90**	**GN3-100**	**GN5-5**	**GN5-30**
Weighted Time exposed in rain (min)	4	4	4	4	4	1	1	4
Weighted Time exposed in dry (min)	5	11	11	11	11	1	1	11
Total Weighted Time exposed to Rockfall (min)	9	15	15	15	15	2	2	15

Location		**Grunters**			
Hazard ID	**GN5-100**	**GR1-85**	**GR2-10**	**GR2-20**	**GR3-1**
Recommendaed mitigation		**new rockfall sign**	**new rockfall sign**	**temporary fencing erected each summer (Nov to April) and new rockfall sign**	**new rockfall sign**
Comments					New location
Main Hazard Type Assessed	Rockfall	Rockfall	Rockfall	Rockfall	Rockfall
Risk scenario	Collapse of overhanging fragmenting and rolling to footpath	Collapse of overhang impacting beach users	Collapse of overhang impacting beach users	Collapse of overhang impacting beach users	
R_{DI} (without risk mitigation recommneded)	7.6E-07	7.8E-08	1.3E-07	6.2E-06	4.0E-06
$P_{(H)}$	1.0E-01	1.0E-01	1.0E-01	1.0E-01	1.0E-01
$P_{(S:H)}$	3.5E-02	3.6E-03	6.2E-03	2.9E-01	1.9E-01
$P_{(T:S)}$	2.9E-05	2.9E-05	2.9E-05	2.9E-05	2.9E-05
$V_{(D:T)}$	0.5	0.5	0.5	0.5	0.5
N	15	15	15	15	15
R_{SOC}	5.0E-07	5.2E-08	8.9E-08	4.1E-06	2.7E-06
R_{LOL}	5.0E-08	5.2E-09	8.9E-09	4.1E-07	2.7E-07
Total individual visitors at any one time	10	10	10	10	10
R_{CI}	3.53E-03	5.17E-05	8.88E-05	4.12E-03	1.34E-04
N_T - total number of individuals visiting the site each year (assuming no repeat visits)	70000	10000	10000	10000	500
Total individual visitors per day in a year	192	27	27	27	1
Risk Variable breakdown					
P_H					
Return Interval for Rockfall (once every ? Yrs)	10	10	10	10	10
$P_{S:H}$					
Length of Trajectory where people could be impacted (m) if rockfall is main hazard	22	11	16	25	5
Width of block (m)	4.0	4.0	1.0	15.0	5.0
Potential Impact area (m^2)	88	44	16	375	25
% of Trajectory where humans could be impacted that gets hit by rockfall or affected by collapse	25%	5%	30%	50%	75%
Assumed Spatial Impact Area (m^2)	22	2.2	4.8	187.5	18.75
Approximate general area in front of hazard a proportion of which will be in the impact area (m^2)	623	607	771	650	100
P_{TS}					
Minutes per year	525600	525600	525600	525600	525600
% significant rockfall in Rain	80%	80%	80%	80%	80%
% significant rockfall in Dry	20%	20%	20%	20%	20%
Time Spent in Rockfall Hazard Zone if raining (min)	5	5	5	5	5
Time spent in Rockfall Hazard Zone if dry (min)	55	55	55	55	55

Location		Grunters			
Hazard ID	**GN5-100**	**GR1-85**	**GR2-10**	**GR2-20**	**GR3-1**
Weighted Time exposed in rain (min)	4	4	4	4	4
Weighted Time exposed in dry (min)	11	11	11	11	11
Total Weighted Time exposed to Rockfall (min)	15	15	15	15	15

Appendix C
Sign Audit

PER2021-0300 Appendix C - Sign Audit

Report Sign ID	Shire ID	Easting	Northing	Comments	
SR01	-	313657	6251007	Good condition and well positioned	
SR02	125	313679	6251010	Sign not present but not required	
SR03	127	313623	6251001	Poor condition. Replace with 'rehabilitation area' sign	
SR04	-	313574	6251012	Place new 'rockfall hazard' sign at the entrance to the risk area	
SR05	-	313461	6250950	Poor condition. Replace with 'rehabilitation area' sign	
SR06	-	313460	6250948	Good condition and well positioned	

SR07	0			Old, in poor condition, needs to be replaced with standard “rockfall hazard area” sign as per SR06	
SR08	-	313342	6250918	Not on shire database. Remove sign as it is not directly applicable to the rockfall area.	
SR09	-	313349	6250912	Install standard “Rockfall Hazard Area”sign.	
SR10	315	313338	6250891	Sign missing. Replace with “Rockfall Hazard Area”sign.	
SR11	-	313320	6250887	Two separate signs. Good condition and well positioned	 

SR12	-	313271	6250857	Good condition and well positioned. However consider replaced with standard “Rockfall Hazard Area” sign for uniformity.	
SR13	-	313437	6250911	Good condition and well positioned	
SR14	-	313308	6250904	Install “Rockfall Hazard Area”sign.	
SR15	-	313981	6238844	Sign to be replaced ‘Rehabilitation area keep off dunes’ sign or similar wording.	
SR16	-	313965	6238506	Install rockfall “Rockfall Hazard Area”sign.	
SR17	-	313938	6238692	PR3-165 Good condition and well positioned.	

SR18	-	313909	6238616	Good condition and well positioned	
SR19	-	313913	6238619	Good condition and well positioned	
SR20	-	313918	6238610	Good condition and well positionedposition	
SR21	348 (?)	313909	6238616	Sign missing. Replace with sign – “Rockfall Hazard Area”sign”.	
SR22	-	313917	6238564	Sign missing. Replace with “Rockfall Hazard Area”sign.	
SR23	345	313896	6238600	Good condition and well positioned.	

SR24	341	313928	6238547	Good condition and well positioned.	
SR25	0	313940	6238562	Signage to be improved. Install “Rockfall Hazard Area”sign at eye level. Also consider signage relating to not damaging vegetation, such as a rehabilitation area sign.	
SR26	340	313986	6238518	Good condition and well positioned for the hazard. However for someone to see this sign they will have already traversed many metres off formal tracks from the Main Break Carparking area. This sign if however located on an informal track.	
SR27	-	314044	6238453	Good condition and well positioned.	
SR28	353	314276	6238398	Sign missing. Replace with “Rockfall Hazard Area”sign.	
SR29	57	314248	6238430	Sign not present. Replace with “Rockfall Hazard Area”sign.	

SR30				Good condition and well positioned. Signage at fence including informative signs and small signs on fence posts are in good condition.	
SR31				Remove sign - this sign is now redundant	
SR32	14	314491	6237091	Good condition and well positioned.	
SR33	-	314434	6237033	Add “Rockfall Hazard Area”sign.	
SR34	-	314424	6237027	Good condition and well positioned.	

SR35	-	314336	6237021	Rehabilitation sign - good condition. Add “Rockfall Hazard Area”sign.	
SR36	77	314333	6237017	Good condition and well positioned	
SR37	-	314306	6236992	Temporary signage to be made permanent.	
SR38	91	314302	6236991	Temporary signage to be made permanent.	

SR39	-	314299	6236987	Add permanent 'Imminent Rockfall Risk' same design/wording as the Riflebutts Cliff signs	
SR40	364	314310	6236929	Good condition and well positioned	
SR41	-	314334	6236838	Good condition and position. Recommend adding new rockfall hazard signs as informative sign to both entrances to the Back Beach (bottom of stairs), with a map showing hazard locations and suggested areas to avoid i.e. parts of the beach below GN1-25 and GN1-50	
SR42	-	314461	6236718	Good condition and well positioned. An additional sign should be added to be viewed on entrance to the beach (i.e., on the fence perpendicular to the current sign). Recommend adding new rockfall hazard signs as informative sign to both entrances to the Back Beach (bottom of stairs), with a map showing hazard locations and suggested areas to avoid i.e. parts of the beach below GN1-25 and GN1-50	

SR43	-	314896	6236054	Good condition and well positioned	
SR44		314763	6235982	Add “Rockfall Hazard Area” sign on beach directly in front of GR1-85	
SR45		314726	6236000	Add “Rockfall Hazard Area” sign on beach directly in front of GR2-10	
SR46		314710	6236027	Add “Rockfall Hazard Area” sign on beach directly in front of GR2-10. Consider educational/informative sign and beach map at beach entrance illustrating hazard area to avoid on beach below GR2-10 as this area is used by surf schools.	
SR47		315005	6235707	Add small “Rockfall Hazard Area” sign on beach approximately 5 m in front of hazard . New location	

Appendix D
Definitions

The definitions used within the risk assessment (Appendix B) follow the same format as the previous report conducted by Golder and are shown below.

Risk for individual most at risk, R_{DI} = P_H x $P_{S:H}$ x $P_{T:S}$ x $V_{D:T}$ x N

P_H – annual probability of rockfall or slope collapse occurring of sufficient size to cause loss of life

$P_{S:H}$ – the probability of spatial impact

$P_{T:S}$ - the temporal spatial probability for recreational users, the probability that a person will be in the hazard zone at any given time of the year

$V_{D:T}$ – the vulnerability of the individual

N – the average number of times the person most at risk visits a location each year

Total Societal Risk , R_{SOC} = R_{LOL} x N_{SOC}

R_{LOL} referred to as IR_{DI} in the Golder 2017 – individual risk of death for each person who visits a site

This risk is the same as R_{DI}, but does not account for repeat visits by the same person

N_{SOC} – potential number of people that could die in a single rockfall or collapse event

Cumulative Individual Risk, R_{CI} = R_{LOL} x N_T

N_T – total number of individual visitors to a site each year

- **Risk** – A measure of the probability and severity of an adverse effect to health, property or the environment.
- **Hazard** – A condition with the potential for causing an undesirable consequence (in this case, rockfall or ground collapse).
- **Hazard Zone** – An area within which the hazard may affect elements at risk if failure were to occur.
- **Elements at Risk** – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by the hazard.
- **Probability** – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome and 1 indicating that an outcome is certain.
- **Frequency** – A measure of the likelihood expressed as the number of occurrences of an event in a given time.
- **Likelihood** – Used as a qualitative description of probability or frequency.
- **Temporal Probability** – The probability that the element at risk is in the area affected by the slope failure, at the time of the slope failure.
- **Vulnerability** – The degree of loss to a given element or set of elements within the area affected by the hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.
- **Consequence** – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.
- **Individual Risk** – The risk of fatality or injury to any identifiable individual who enters the hazard zone.
- **Societal Risk** – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a slope failure causing a number of deaths, injuries, financial, environmental, and other losses.
- **Acceptable Risk** – A risk that, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.
- **Tolerable Risk** – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible. In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

Figure – Risk Definitions - Golder Associates 2017; Limestone Cliff Stability Assessment - prepared for the Shire of Augusta Margaret River (reference 1666765-001-R-Rev0, dated May 2017)