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Portland Coastal Stability Assessment – Reassessment of Risks May 2018

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Prepared jointly for

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1. Executive Summary

Portland experienced heavy and prolonged periods of rainfall during 2013 which corresponded with significant landslide activity on the section of coast between Nuns Beach and Anderson Point. As a result, a number of paths and tracks were impacted and concerns for public safety were expressed by the Glenelg Shire Council (GSC) and some members of the public.

In response, the then Department of Environment and Primary Industries (DEPI) and Glenelg Shire Council (GSC) jointly initiated a series of site inspections and reviews and commissioned A.S. Miner Geotechnical (ASMG) to carry out a geotechnical inspection and assessment of the hazards and associated risks. A report was prepared in 2013 by ASMG which detailed findings from those investigations and made appropriate comments and recommendations regarding ongoing management of the area.

Following this initial report, ASMG undertook an inspection of the study site for The Port of Portland Authority as well as conducting a signage and barrier audit at the site for GSC, both in early 2014.

In the intervening time since, the restrictions to public access first imposed in 2013 have remained in place and no further formal assessment of risks has been undertaken although some remedial works have been undertaken most notably at the Nuns Beach slide and at the rear of the caravan park through relocation of the rear boundary to address Hazards H42, H43 and H44 (as designated in the 2013 report) , adjacent to the Great South West Walk path.

More recently, GSC in association with the Department of Environment Land Water and Planning (DELWP) have expressed interest in revisiting the issue of risk at the site and to review the ongoing restriction to public access partially in recognition that some members of the public are ignoring signage and barriers and continue to use the coastal walk below the cliffs between Clifton Beach and Nuns Beach.

In addition GSC have also requested ASMG to expand the initial study area to include new areas of interest along the northern and southern sections of the Lee Breakwater Road.

This current report reviews the site conditions, makes comparisons with previous hazards, identifies new hazards and re-assesses risk levels. The report also provides brief discussion on potential management options and looks at remedial works in a broad conceptual way.

A number of important issues and outcomes from the current study are discussed which include:

- Recognition of 7 geographic zones and 26 geomorphic domains was made to better describe the full extended study area
- Identification of a total of 78 individual hazards and general areas of hazards across the original and new study areas. This comprises the following
    - 52 previous hazards observed in the initial study area
    - 7 new hazards in the initial study area
    - 6 hazards in the new study area along the northern section of the Lee Breakwater Road, south of Nuns beach
    - 13 hazards and general hazard areas in the new study area within the southern Lee Breakwater Road area adjacent to the main harbour
- Identification of 10 different mechanisms/modes of failure
- More explicit definition of the context of the assessment of risk with respect to DELWP and GSC objectives and intentions for the site and its use and management

- Further assessment of rainfall has been undertaken to improve understanding of its importance as both a preparatory factor and a triggering factor for regional and site landslide activity

The previous preliminary assessment of risk was conducted using the Australian Geomechanics Society's (AGS) Landslide Risk Management Guidelines (AGS 2007). However, the re-assessment of risk in this project expands on the AGS risk assessment approach through integration with DELWP's Risk Management Guidelines (Zeeher and Khoo 2017) and in particular the adopted risk revaluation criteria and protocols for treatment, management and reporting.

It is noted that whilst many considerations must ultimately be applied in how to manage risk to meet both organisational and community expectations, this current risk assessment focuses mainly on public safety and wellbeing.

An initial screening process was adopted to reduce the 78 individual hazards down to 25 key issues. Correlation between the AGS and the DELWP risk guidelines was then undertaken and using the DELWP guidelines as the guiding protocol for risk assessment and evaluation at this site, it was concluded that a number of combinations of hazards and exposed elements at risk fall into **High Risk** levels. These include:

- Users of the Anderson Point stairs due to shallow slide (Hazard H1a) below lower landing
- Walkers along path below Whalers Point due to rockfalls from upper section of cliff source from Hazard H45 and H47and collectively designated as Hazard NH55a
- Walkers along the path below Whalers Point due to isolated rockfall from Port Campbell Limestone (PCL) and the Werrikoo flaggy limestone bed from Hazard NH52 and right on the point from Hazard NH54

In addition, a number of combinations of hazards and exposed elements at risk fall into **Significant Risk** levels and these include:

- Walkers on the path below slides above the PCL from hazards H13, H16 and H55 at Whalers Point and from Hazard H23 on the Nuns beach section.
- The Great South West Walk (GSWW) trail itself from ongoing retrogression at the cliff top from Hazards H48 and H49
- The outer fence at the Whalers Point lookout from retrogression from Hazards H45 and H47

A number of hazard and elements at risk combinations present as **Medium to Significant Risk** and these include

- Walkers on the path below Whalers Point due to potential cliff face collapse in the PCL from Hazard NH53
- Pedestrian's on the footpath on the southern section of the Lee Breakwater Road due to rockfall from PCL and /or collapse of bluestone blocks placed directly above the PCL

Other combinations fall into the **Medium Risk** level and include;

- Walkers on the beach path at Clifton Beach due to a soil slide from the upper cliff profile at Hazard H5
- Users of the main beach access stairs at Nuns Beach due to Hazard H41
- Occupants of vehicles using the northern Lee breakwater Road from slides in XW Basalts and Tuffs designated as Hazards NH57 and NH58
- The fencing along the southern Lee Breakwater Road

All other combinations of risk and hazard fall into the **Low Risk** category

Management of risk and the need for both risk mitigation (to reduce levels of risk) and risk treatments (to manage levels of risk) can be related back to the DELWP Risk Management Guidelines which provide guidance on risk treatment and report requirements, which in summary states:

- **High Risk** falls outside DELWP's risk appetite and would require active monitoring, risk treatments, management options that reduce risks to as low as reasonably possible (ALARP) and significant reporting activities
- **Significant Risks** may fall outside DELWP's risk appetite and would require a risk treatment plan, management options to ALARP principles and regular monitoring and reporting
- **Medium Risk** falls within DELWP's risk appetite and may be managed without further treatment but still require regular monitoring on a 6 monthly basis
- **Low Risk** falls well within DELWP risk appetite and would still require appropriate levels of monitoring and reporting

The final adoption of risk mitigation plans and treatments is, by necessity, based on both DELWP's and GSC's organisational interpretation of the DELWP guidelines to ensure public safety and well-being whilst also considering other factors which might include (but not be limited to) financial, legal, political and/or reputational .

As such, a further phase of discussion and direction with both DELWP and GSC is required before finalisation and choice of preferred risk treatment options can be undertaken.

However, on the basis of the stated objectives of the current project with respect to public access and safety, the significant previous work completed on various remedial options and the use of the DELWP guidelines as an overall general guide to potential organisational position of risk, ASMG has collated a table of possible remedial and management options for consideration by DELWP and GSC.

In conclusion, any risk management approach for the site should include critical risk treatments and mitigation works in combination with management protocols based on the best available data and information. It is expected that it is only through a combination of risk treatment measures, appropriate review and the assessment of performance based indicators that a level of site amenity can be returned.

As such the following recommendations are proposed as a way forward for the site. It is recommended, subject to resources and funding being made available, that:

- Review of the proposed risk treatments and mitigation works to be undertaken for each site provided in this report and specific options chosen for sites made as a result of consideration of a broad range of stakeholder factors.
- An ongoing monitoring of regional rainfall patterns should be immediately commenced with particular emphasis on the longer term cumulative totals which are postulated as a good proxy for overall groundwater levels with protocols.
- Develop a management plan for stakeholders that links threshold values with management actions with clear operational and procedural protocols
- An inventory of failures must be developed and maintained with all new landslide hazards documented with similar level of information as detailed in this report.

- It is recommended that all paths and open space closures remain in place until remedial works and management options are implemented
- Consider a public information and awareness program aimed at increasing understanding of the dynamic nature of the coastal setting and informing people of the potential hazards.

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2. Introduction and Background

Coastal instability and erosion have been long recognised as significant factors in the dynamic nature of the coastline in and around the township of Portland in the far southwest of Victoria (see Figure 1). Early reports on the complex geology of the region noted evidence for significant landslides including slides (sometimes known as slumps) and rockfalls on the coast as well as other geological hazards such as sinkhole and karstic features (Boutakoff 1963).

A number of past investigations and studies looking at general aspects of instability as well as specific landslide occurrences have been prepared over the past 40 years. Such studies included the widely reported Hanlon Parade landslide in 1974 and more recently the significant 2008 Wade Street (Anderson Point) landslide.

Portland experienced heavy and prolonged periods of rainfall during 2013 which corresponded with significant landslide activity on the section of coast between Nuns Beach and Anderson Point. As a result, a number of paths and tracks were impacted and concerns for public safety were expressed by the Glenelg Shire Council (GSC) and some members of the public.

In response, the then Department of Environment and Primary Industries (DEPI) initiated a series of site inspections and reviews and commissioned A.S. Miner Geotechnical (ASMG) in 2013 to carry out a geotechnical inspection and assessment of the hazards and associated risks. A report was prepared which detailed a preliminary risk assessment and which also made comments regarding site management and potential remedial works.

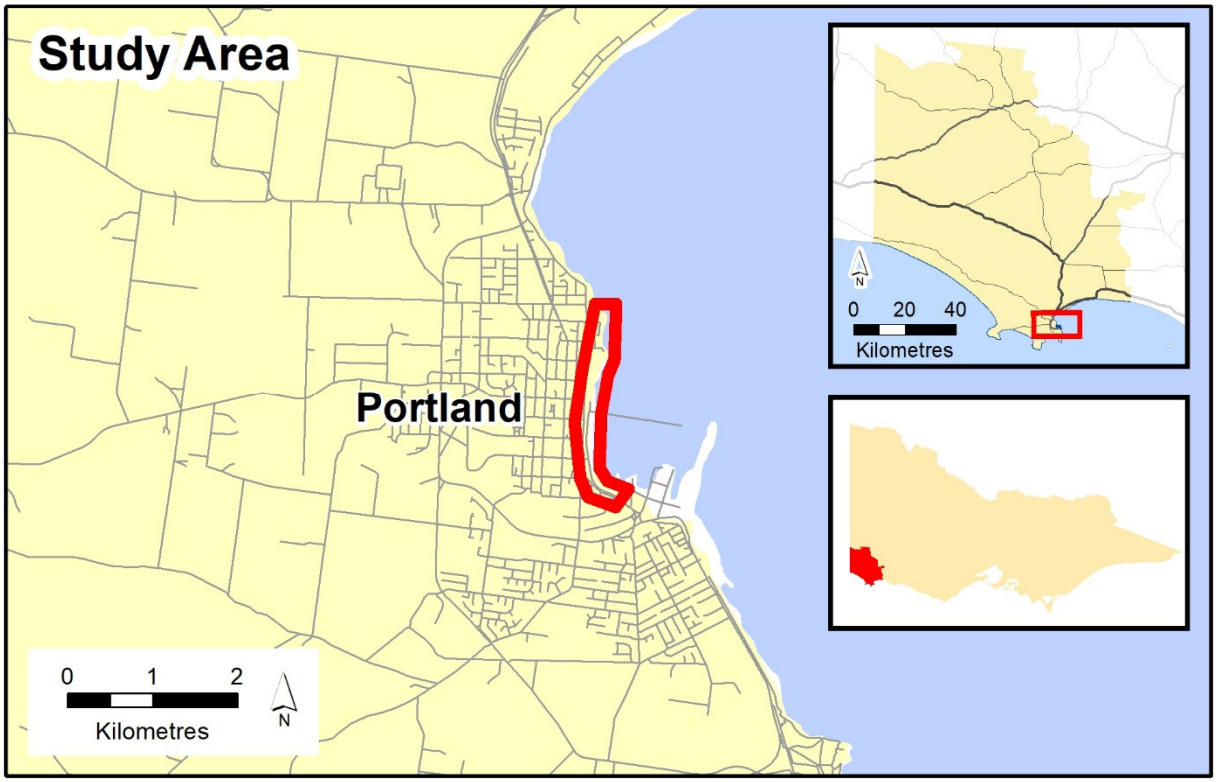

Figure 1 Location Map

Following on from this initial preliminary risk assessment report in 2013, ASMG then undertook further inspections at the site in Feb 2014.as part of review work for the Port of Portland Authority to help inform a risk workshop related to sand pumping operations.

ASMG then later undertook an audit of signage and barriers at the site in April 2014 to assist Glenelg Shire Council (GSC) in better managing the risk associated with the landslide activity of August 2013.

In the intervening time since, no further formal assessment of risks has been undertaken although some remedial works have been undertaken most notably at the Nuns Beach slide (previously designated as Hazard H40 in the previous 2013 report) and at the rear of the caravan park through relocation of the rear boundary to address Hazards H42, H43 and H44

More recently, GSC in association with the Department of Environment Land Water and Planning (DELWP) have expressed interest in revisiting the issue of risk at the site and to review the ongoing restriction to public access partially in recognition that some members of the public are ignoring signage and barriers and continue to use the coastal walk below the cliffs between Clifton Beach and Nuns Beach.

The original study area has been expanded to include new areas of interest along the northern and southern sections of the Lee Breakwater Road as part of this update to the original report..

This report again reviews the site conditions, makes comparisons with previous hazards, identifies new hazards and re-assesses risk levels. The report also provides brief discussion on potential management options and looks at remedial works in a broad conceptual way.

3. Scope of Works

The works undertaken in this current study are part of a Coastal Public Access and Risk (CPAR) Grant (2017-2018) provided by DELWP working in partnership with Glenelg Shire Council.

As described in the grant funding application, discussions were undertaken with DELWP seeking support for GSC to update the earlier ASMG report (Ref: 734/02/13) entitled: "*Portland Coastal Stability Assessment – September 2013*".

The objective of the CPAR is to provide financial assistance to coastal Crown land managers for projects that reduce coastal risk through identification, mitigation and monitoring. Given the range of risks that are inherent in a dynamic coastal environment, this program aims to support a strategic and balanced approach to risk management along the Victorian coast.

A.S. Miner Geotechnical (ASMG) was commissioned by Glenelg Shire Council (GSC) via purchase order (dated 1st February 2018) to update and extend the 2013 ASMG report.

The scope of works as described in an initial earlier email dated the 17th May 2017, was as follows:

1. *Review the existing (north of breakwater) report works and update the report,*
2. *Extend the study area to the south of breakwater to the Trawler Wharf Road in a similar layout of the existing report 734/02/13. The area behind the Portland Naval Sea Cadets building is of interest as it has some recent minor slips*

An initial project set up meeting was organised at GSC offices in Portland on the 5th March 2018 which sought to clarify issues regarding the overall intent of the project and to allow clarification of the project proposal which subsequently include the following tasks:

- Seek historical information from DELWP including aerial photographs, reports and other information.
- Undertake meeting with DELWP risk department regarding risk acceptance criteria and DELWP's position on risk sharing and community risk expectations.
- GSC to collect all rockfall and failure inventory, maintenance records, Facebook posts, surveys, questionnaires and any other community based anecdotal evidence of activity at the site.
- GSC to contact Port of Portland Authority (POPA) and seek information on working protocols, and any evidence of activity for POPA sand pumping process in the past few years.
- ASMG to undertake field inspections and assessments of original study area and new extended area. Include top and bottom of cliff and retaking of GPS enabled site photo at key locations.
- Identify all hazards, Assemble inventory of old and new failures and undertake re-assessment of risks.
- Workshop preliminary findings with GSC and DELWP to detail observed hazards, to confirm project risk appetite and objectives for remedial treatments and/or ongoing management.
- Provide final report

4. Site Description

4.1 Study Area

The study area as defined in the initial study extended from Nuns Beach carpark in the south to Anderson Point in the north. This represented an approximate distance of 1100 m along the foreshore and includes both the lower and upper sections of the coast.

The study area was extended for this current study to include a section south of the original area to include an area along the northern section of Lee Breakwater Road from the Nuns Beach carpark to section of low cliff just opposite Henty Street. This sub area measures approximately 460 m along the cliff alignment.

In addition, a third area was added to the new study area and includes a section of cliff along the southern section of the Lee Breakwater Road running from opposite Cliff Street to Glenelg street and measuring approximately 450 m along the cliff alignment.

The full extent of the new study area is shown in Figure 2.

4.2 Site Conditions

Information relating to the site description has been previously provided in a number of reports contributed to and/or prepared by ASMG which includes:

> *"Portland Wade Street Landslip – Investigation, Monitoring and Analysis of a Landslip. February 2009 Parsons Brinckerhoff report Number 2124301B-RPT_003-B (M09010)"*
>
> *"Portland Coastal Stability Assessment- September 2013. Report No: 734/02/13. Date 16th October 2013. Prepared by A.S.Miner Geotechnical jointly for Department of Environment and Primary Industry and Glenelg Shire Council."*

Detailed discussion has been previously provided which specifically relates to the following:

- Climate
- Geomorphology
- Geology
    - Structural setting
    - Stratigraphy and Lithology
- Hydrogeology

Specific detail on these topics has been reproduced in Appendix A.

5. Comment on Past and Recent Instability in the Area

Previous review of past slope instability in the Portland area was undertaken in the 2013 ASMG report and details are reproduced in Appendix B.

Based on this data, it was concluded that instability very often involves failures within the upper weathered basalts. The smaller cliff recession failures (ranging from 2.0m to 5.0 m) generally occur in the upper highly weathered (HW) to extremely weathered (XW) basalts. The larger failures (extending beyond 10.0 m recession) such as the Hanlon Parade and Wade Street landslides tend to involve a full profile of weathered basalt and the underlying Maretimo clays which provide a preferential failure plane below the jointed and weathered basalt.

The other strong evidence in this compilation, notwithstanding this inventory is incomplete, is that failure very commonly occurs at the end of winter / start of spring. This correlates with the highest rainfall months and probably reflects the time of highest seasonal groundwater levels as the upper basalts are considered to be quite permeable due to their jointing and weathering

Following the completion of the original ASMG report in 2013 including the observations of a significant number of new failures as a result of the heavy rains in 2013, a number of other site observations of instability have been made by ASMG and others in the intervening time leading up to the most recent site inspection by ASMG in May 2018. As a result, a further inventory of additional observed events has been collated and these are presented in Table 1 below.

In summary, landslide activity has continued within the study area although on a much reduced scale compared to the very significant events in August 2013. Whilst no further medium and /or large slide type failures have been recorded, some smaller slides have remained active (see later comment regarding Hazard H1a at the Anderson Point stairs)

However, of more significance is the fact that small rockfalls have been ongoing from 2014 to 2018 with the main focus for activity in the area around Whalers Point. Falls have occurred from both the upper profile of weathered Basalts and from the lower Port Campbell Limestone (PCL). Falls are still regularly reaching the walking path located between the rock seawall and the base of the cliff.

Date	***Location***	***Description***	***Source***
Prior to Feb 2014	At the site of Hazard H45	Further upper level rockfalls in HW Basalt from the steep vertical face at H45 were noted from oblique photos taken below. These falls were presumed to be lodged on the mid-level bench	ASMG (Feb 2014)
Prior to Feb 2014	At the site of Hazard H23	Minor falls from XW basalt and flaggy limestone above PCL. No evidence that falls travelled as far as path	ASMG (Feb 2014)
Prior to Feb 2014	Path below Whalers Point between H11 and H20	Numerous small diameter (0.1 m to 0.2 m) cobble sized falls from upper XW basalt. Also one or two minor falls from PCL also noted on path	ASMG (Feb 2014)
Prior to 30th March 2014	Overall site	Unchanged from Feb 2014 inspection. With no sign of groundwater seepage or further significant recent falls or new areas of instability	ASMG (April 2014)
22 June 2015	Lee Breakwater northern end of NH65	Fall in bluestone blocks at start of section just to south of “escape tunnel”	J Hogan (email)
Jun 2016	150 m south of Nuns beach on Lee breakwater Rd	Cliff edge or roads slips, Fallen rocks <200mm and profile reshaped with less than 0.5m3 removed	M. Armstrong (2018 pers comm.)
Aug 2017	150 m south of Nuns beach on Lee breakwater Rd	Cliff edge or roads slips, Fallen rocks <200mm and profile reshaped with less than 0.5m3 removed	M. Armstrong (2018 pers comm.)
25 Sept 2017	Site of Hazard H48 in behind Clifton Court	Retrogression of gully at hazard H48 due to stormwater flows out of hidden pipe?? Reported by Paul Healey	M. Armstrong (2018 pers comm.)

Table 1 Further observations of instability relevant to the study site b/n 2014 and 2018

6. Historical Photography Interpretation

To assist in the collation of previous information on slope instability at the area, an assessment of historical aerial photographs was undertaken. A series of past aerial images were provided by DELWP for review and assessment and details are listed in Table 2 below.

Date	***BW/Colour***	***Scale***	***Height***	***Geo-referenced***
??/??/1947	BW			Yes
27/04/1968	BW	1:6300	2100	No
09/12/1969	BW	1:12000	6000	No
14/12/1972	BW	1:25000	12800	No
01/05/1981	Colour		7500’	No
27/10/1985	BW	1:4000	2100’	No
11/05/1990	BW	1:4000	2100’	No
01/11/2003	Colour			Yes
23/02/2010	Colour			Yes
22/12/2012	Colour			Yes
30/1/2014	colour	GooglEearth		
??/??/2018	Colour			Yes

Table 2_ List of Historical photography now available for interpretation

Historical aerial photographs have been collated in Appendix C whilst specific details of the historical interpretation and assessment are provided in Table 3.

In summary, whilst much of the fine site scale detail is unable to be assessed due to varying image quality and resolution, there is still clear evidence of past landslide activity within the study area with both slides and even smaller rockfalls being able to be identified in various images. As such, the historical assessment provides good corroboration that these landslide processes have been active in the past and are not just a result of the heavy and prolonged rainfall experienced in 2013.

In addition, the historical photographs also catalogue significant changes to the foreshore within the study area over time. Construction of the rock seawall, which was present in 1972 initially only ran from Nuns Beach to Whalers Point. However by 1985 the rock seawall extended beyond Whalers Point to Anderson Point.

As a result, the construction of the seawall and the bypass pumping of sand from the harbour to initially Nuns Beach and then later to Anderson Point has significantly altered the backshore area behind the wall and the nearshore area with accumulation of sand modifying both the subtidal and intertidal zones.

Date	*Overall comment about quality of image*	*Anderson Point*	*Clifton Beach*	*Whalers Point*	*Nuns Beach*	*Lee Breakwater South*
1946-47	Poor quality image small relative scale and poor clarity of features	No features obvious. Sandy beach both north and south of point	Broad sandy beach	Point seems to extend slightly further seaward. Possibly rocky shore platform exposed	Broad sandy beach present	No features on cliff discernible at this scale. Sandy beach present prior to harbour construction
1968						Appears to be more of the white cliffs exposed and perception of debris at toe of slope.
1969	Relatively crisp clear image	Distinct shore platform at point with cobble boulder beds?	Virtually no sandy beach and exposed PCL. Possibly sea caves below 13 Clifton Court. Talus/scree rock in a number of locations along this section suggest falls in PCL	No evidence of H45/H13 Older feature H55 is clearly evident and is an older slide Numerous boulders on beach (PCL = basalt??) Note fence at lighthouse is well away from cliff edge	Two rock groynes now evident (one opp. Fern St and one opp. south end of caravan park) plus rock seawall from 1st groyne to Whalers Point. Recent slide with headscarp ½ way between Fern St and caravan park. Broad beach between 1st groyne and breakwater	Prominent exposures of PCL in cliff but no other features obvious except for placement of individual limestone boulders opp. 65 Cliff Street

Table 3 Comments relating to Historical Aerial Photograph Assessment

Date	*Overall comment about quality of image*	*Anderson Point*	*Clifton Beach*	*Whalers Point*	*Nuns Beach*	*Lee Breakwater South*
1972	Generally clear image despite high elevation	Slides evident either side of Anderson Point with precursor to Wade Street slide very clear. Little sand at point.	Crenulated coastline formed in PCL directly below No 13 Clifton Crt and little to no sand. Possible sea cave and edge looks active suggesting fall activity form overhangs in PCL No sand at all and coastline looks quite linear	No evidence of any of the recently observed failures. Rock seawall has been constructed up to the point now and a captured sandy buffer area exists between cliff and seawall with track marks. Possibly indicative of the initial sand pumping bypass release point??	Broad sandy beach between 1st groyne and breakwater	Strong exposure of PCL but no further features obvious
1981	Fair overall quality , taken at significant height	Slide to the north of point remains active. Wade Street precursor is more subdued but with clear side and headscarp. Some activity and rock exposure on beach south of the point at future stair landing. no sand on exposed platform	Seawall now extended almost to Anderson Point. Lagoon forming below Clifton Crt with clearly exposed PCL cliff Fresh slide in residual soil/basalt above PCL opp. No 1 Clifton Crt at site of H2	Appears to be a recent rockfall at H16	Recent slide from XW basal opp. 133 Bentick Street Beach and rock seawall unchanged.	Strong exposure of PCL but no further features obvious

Table 3 (Cont.) Comments relating to Historical Aerial Photograph Assessment

Date	***Overall comment about quality of image***	***Anderson Point***	***Clifton Beach***	***Whalers Point***	***Nuns Beach***	***Lee Breakwater South***
1985	Excellent quality high resolution	Very slight sand accumulating in behind rock seawall. Fresh cliff edge exposure evident on edge of wade street slide	Lagoons still evident between PCL cliff line and seawall. Lot of activity within basalt over PCL in this section with numerous slides H49 and H48 becoming active and are evident now	Some bare earth exposure at H47 above H13. Also possibly activity at H45 Note fence around lighthouse is still quite a distance away from cliff edge	No activity at H23 Broad beach maintained south of groyne Little change	Some individual rockfalls are evident in the southern and central sections of the site. All are within fence line
1990	Very dark and poor quality for interpretation	Area generally appears well vegetated with no bare exposures or obvious failures	Area generally appears well vegetated with no bare exposures or obvious failures, Possible lagoons?? Hazards H49 and H48 are visible	Shadow obscures views	Extensive sand placement on northern section from sand pumping. Waves breaking well offshore	
2003	Poor quality, not sharp and quite image	Sand now in front of seawall exposed. Possible slide at site of H1a	Significant sand now in front of seawall No lagoons	Bare exposures at Hazards H47 and H45 Fence around lighthouse now pushed out to cliff edge	Significant sand well established in front of seawall extending all the way to the breakwater	Very poor view of exposures on cliff

Table 3 (Cont.) Comments relating to Historical Aerial Photograph Assessment

Date	***Overall comment about quality of image***	***Anderson Point***	***Clifton Beach***	***Whalers Point***	***Nuns Beach***	***Lee Breakwater South***
2010	Good image quality	Stairs in place .Wade street slide remedial works underway. Slide H1 clearly evident	Hazards H49 and H48 are becoming more evident	Bare earth at H47 suggests some activity??	Broad beach still evident in front of seawall and for entire area. No other obvious activity	Exposure of PCL but quality too poor to pick out any detail
2012	Very good image and high resolution	Sand pipe now visible at point. No significant indication of hazards 1a and 1 b. Wade Street slide now fully remediated	Recent retrogression on H48. Less sand in front of the seawall here	Shadow on photo obscuring features. Possibly isolated rockfall on path below H45 and near H18	No obvious activity in this section. Less sand in front of seawall	
2014	Only fair image at higher resolution	Hazard 1b very clear	No clear activity evident	Not much clearly evident Activity at H47 very evident Suggestion of falls below H45 on path??	Possible activity evident at H40	Poor quality image makes interpretation difficult
2018	Very good quality and high resolution. Lighting very even	Clear recent activity at H1c and H1b Sand pipe exposed on beach below wade street slide	Isolated rockfall on path Recent activity at H49 and H48 Isolated boulders below H9	Exposed faces at H47 and H45. H13 and H16 now present. Rockfalls on path clearly evident especially to outside of path below H45	New hazard (rockfall in PCL) identified 20m SW of H22. H23 exposed. H25 now evident Isolated PCL boulder at H28. Recent falls at H30. H40 now remediated. H57 and H58 now evident	Individual boulders behind fence are clearly evident

Table 3 (Cont.) Comments relating to Historical Aerial Photograph Assessment

7. Site Observations

7.1 Introduction

Following ASMG receiving project authorisation to proceed, an initial reconnaissance site inspection of the study area was conducted by ASMG on the morning of **5th March 2018** in the company of Frances Northeast (DELWP) and Malcolm Armstrong (GSC) as a precursor to the project set meeting held on the same day at GSC council offices.

A detailed site inspection was then subsequently undertaken by Tony Miner (principal geotechnical engineer, ASMG) over a 3 day period from the **29th April 2018 to the 1st May 2018**.

7.2 Geographical Zones

To further assist in the inspection and assessment phases of this report, the initial study area was subdivided into 4 main *geographical zones or locales* as follows;

- Nuns Beach
- Whaler's Point
- Clifton Beach (also sometimes known as Whaler's Beach)
- Anderson Point

As a result of the extension of the study area for this study 3 new geographical zones have been added

- Lee Breakwater Road North
- Lee Breakwater Road Central
- Lee Breakwater Road South

Figure 2 shows the extents of each geographical zone as adopted for the purposes of this report.

7.3 Geomorphic Domains

In addition, a number of *geomorphic domains* within these geographical zones have been proposed which describe areas of similar geology but which have somewhat different landform and geomorphic processes. As such, the initial study area was divided into 7 geomorphic domains as follows:

- Geo1 (Steep cliffs at Anderson Point)
- Geo2 (Remediated landslide below Wade Street and northern end of Clifton Court)
- Geo3 (Bluff and steep cliffs with moderate beach between Wade Street landslide and the end of Clifton Court)
- Geo4 (Steepening cliffs and narrow beach above a slight drainage depression at the top of the cliffs between end of Clifton Court and Whalers Point)
- Geo5 (Very steep cliffs and no beach at Whalers Point)

- Geo6 (Bluff and steep cliffs with broad beach - northern end of Nuns Beach in front of caravan park)
- Geo7 (Long section of bluffs and moderately steep cliffs with broad beach extending from caravan park to Nuns Beach carpark)

Following on from the extension to the study area for this current study, a series of new geomorphic domains have been added as follows:

- Geo8 to Geo11 (Section of gentler slopes adjacent to the northern sector of the Lee Breakwater Road extending from Nuns Beach carpark south to the start of the extensive section of placed bluestone rock revetment/facing)
- Geo12 (Central sector of the Lee Breakwater Road with placed bluestone rock revetment/facing-generally no hazards)
- Geo13 to Geo 26 (Southern section of the Lee Breakwater Road comprising section of exposed Port Campbell Limestone with some infill sections of placed boulders and gentler slopes at the end

The geomorphic domains as described above are also shown on Figure 2

7.4 Hazard Identification Process

A list of all field observations including previous and new hazard sites and other significant features is detailed in Appendix D. Locations of field points and the sites of existing and new hazards within the extended study area are shown on Figures 3 to 13.

Detailed discussion relating to landslide hazard identification and site features is included in the following sections.

7.4.1 Observations

The term landslide denotes “the movement of a mass of rock, debris or earth (soil) down a slope” (AGS 2007). As such, this broad definition includes slides (sometimes referred to as slumps in non-technical terminology), falls, topples and other mechanisms of failure.

A detailed description of landslide nomenclature used in this report is contained in Appendix E.

Based on observations made over the three days of site inspections, a series of pre-existing and new landslide hazards were identified and catalogued in the newly extended study area.

In total, 78 individual hazards and general areas of hazards have now been identified across the original and new study areas. This comprises the following

- 52 previous hazards observed in the initial study area
- 7 new hazards in the initial study area
- 6 hazards in the new study area along the northern section of the Lee Breakwater Road, south of Nuns Beach
- 13 hazards and general hazard areas in the new study area within the southern Lee Breakwater Road area adjacent to the main harbour

The landslide hazards range in size and nature from *extremely small* soil slides generated only in thin outcrops of the Maretimo Clay to much larger*, medium* sized complex slides involving a range of materials such as residual basaltic soils, XW and HW Basalt with the failure plane planes extending deep down into the underlying Maretimo Clay.

Rockfall hazards include very small to large rockfalls from various materials including XW and HW basalt, Port Campbell Limestone (from both insitu rock and placed boulders of PCL) and placed quarried bluestone blocks.

Detailed observations and information for each hazard (including both the initial hazards and the newly identified hazards) are contained on individual reporting templates presented in Appendix F.

This information has also been collated and summarised in a series of tables which separate hazards out into existing hazards in the initial study area (Table 4), new hazards in the initial study area (Table 5), new hazards in the Lee Breakwater North zone (Table 6) and new hazards in the Lee Breakwater south zone (Table 7).

Locations of the hazards with the corresponding field point are shown on Figures 2 to 12.

Hazard ID	*GPS Pt*	*Site Description*	*Size*	*Type*	*Materials*	*Width m*	*Length m*	*Depth m*	*Volume m^3*	*Runout m*	*Plan Travel Distance m*	*Elevation m AHD*	*Approx. Travel Angle*	*Notes*
H1a	434-435	Anderson Pt	small	2 and 3	XW and HW Basalt	25.0	12.0	0.5	120	1.0 to 2.0	19.2	15.5	37°	
H1b	436	Anderson Pt	very small	3	XW and HW Basalt	10.0	8.0	0.5	12	1.0	6.6	7.0	42°	
H1c	437-438	Anderson Pt	medium	2 and 3	Residual soils XW and HW Basalt	15.0	15.0	1.5	300	4.0 to 5.0	21.7	20.0	41°	
H1d	363	Below Clifton Crt	extremely small	4	Maretimo	1.0	0.5	0.3	<1.0	<1.0	0.0	10.0	vertical	
H2	364	Below Clifton Crt	very small to small	3	XW basalt	5.0	5.0	1.5	38	4.0	13.0	12.0	39°	
H3	365	Below Clifton Crt	very small	2 and 3	HW Basalt	2.0	2.0	1.0	4	7.0	16.0	16.0	42°	
H4	366	Behind Whalers Crt	small	1 and 3	Residual soils to XW Basalt	5.0	7.0	2.5	85	10.0	23.0	15.0	31°	
H5	367	Behind Whalers Crt	small	1 and 3	Residual soils to XW Basalt	10.0	7.5	1.0	75 (at top)	6.0	19.0	12.5	31°	
H6	368	Behind Whalers Crt	very small	1 and 3	Residual soils to XW Basalt	2.0	5.0	0.3	3	4.0 to 5.0	4.5	4.5	34°	
H7	369	Behind Whalers Crt	extremely small	4	Maretimo	1.0	1.0	0.3	<1.0	<1.0	3.0	4.0	36°	
H8	370	Behind Whalers Crt	extremely small	4	Maretimo	2.0	1.0	0.5	1	<1.1	2.5	4.5	50°	
H9	371	Behind Whalers Crt	very small	6	Limestone	2.5	1.5	0.5	2	3.0 to 4.0	5.5	6.0	42°	
H10	372	Behind Whalers Crt	extremely to very small	4	Maretimo	3.0	3.0	0.3	3	1.0 to 2.0	4.2	4.5	40°	
H11	373	Behind Whalers Crt	very small	7	Limestone	2.0	1.5	0.5	2	2.0	3.0	6.0	59°	
H12	374	Below Lighthouse Crt	extremely small	7	Limestone	2.0	1.0	0.5	1	2.0	3.8	6.0	53°	
H13	375	Below Lighthouse Crt	medium	2, 3 and 5	Residual basaltic soil over XW and HW Basalt over Maretimo Clay	20.0	15.0	2.0	600	9.0	18.0	20.0	47°	
H14	376	Below Lighthouse Crt	extremely small	6	Limestone	1.0	1.0	1.0	1	2.5	0.0	5.0	Vertical	
H15	377	Below Whalers Point Lookout	extremely small	1 and 3	Residual soils to XW Basalt	2.5	1.0	0.5	1	2.0	6.0	11.0	59°	

Note: The estimate of travel angle is based on tan-1((elevation of source – elevation of end point) / plan distance)

Table 4 Summary of Observed Landslide Hazards in the Initial Study Area

Hazard ID	*GPS Pt*	*Site Description*	*Size*	*Type*	*Materials*	*Width m*	*Length m*	*Depth m*	*Volume m^3*	*Runout m*	*Plan travel Distance m*	*Elevation m AHD*	*Travel Angle**	*Notes*
H16	378-379	Below Whalers Point Lookout	small	2 and 3	XW and HW Basalt	10.0	3.0	1.0	30	4.0	11.0	15.0	52°	
H17	379	Below Whalers Point Lookout	extremely small	7	Limestone	4.0	2.0	0.1	1	1.5	1.5	4.0	63°	
H18	380	Below Whalers Point Lookout	very small	6	Limestone	3.0	2.0	1.0	6	8.0	8.0	6.0	32°	
H19	380	Below Whalers Point Lookout	extremely small	2	HW Basalt	0.4	0.2	0.2	<1.0	8.0	26.5	30.5	48°	
H20	381	Below Whalers Point Lookout			XW Basalt	1.0	0.75	0.5	<1.0	1.0	3.5	4.5	45°	
H21	382	Below Whalers Point Lookout	extremely small	2	HW Basalt	0.2	0.1	0.1	<1.0	2.0	24.2	30.5	51°	
H22	383	Below Whalers Point Lookout	extremely small	3	XW Basalt	1.5	1.0	0.4	<1.0	2.0	3.0	6.0	59°	
H23	385-386	Below caravan park	very small to small	5	XW Basalt and Maretimo Clays	12.0	2.0	1.0	25	7.0	8.0	10.0	48°	
H24	387	Below caravan park	very small to small	5	XW Basalt and Maretimo Clays	10.0	4.0	0.5	20	4.0	10.0	14.0	49°	
H25	388	Below caravan park	small	2 and 3	XW and HW Basalt	10.0	10.0	0.4	80	3.0 to 4.0	16.0	16.0	37°	
H26	389	Below caravan park	very small	8	Landslide debris	2.5	3.0	0.3	2.25	1.0	9.9	8.0	37°	
H27	390	Below caravan park	Very small	8	Landslide debris	2.5	5.0	0.3	3.75	2.0	4.5	8.0	37°	
H28	391	Below Ploughed Paddock	extremely small	3	XW Basalt	2.0	0.5	0.2	<1.0	<1.0		6.5	60°	
H29	393	Below Ploughed Paddock	extremely small	2 and 3	XW and HW Basalt	1.0	1.5	0.3	<1.0	<1.0		7.5	34°	
H30	394	Below Ploughed Paddock	extremely small	2, 3 and 5	XW and HW Basalt with some Maretimo Clay	1.0	1.0	0.2	<1.0	<1.0		5.5	60°	
H31	395	Below Ploughed Paddock	very small	3	XW Basalt and landslide debris	6.0	4.0	0.3	7.2	2.0 to 3.0		10.0	38°	

Note: The estimate of travel angle is based on tan-1((elevation of source – elevation of end point) / plan distance

Table 4 (cont.) Summary of Observed Landslide Hazards in the Initial Study Area

Hazard ID	*GPS Pt*	*Site Description*	*Size*	*Type*	*Materials*	*Width m*	*Length m*	*Depth m*	*Volume m^3*	*Runout m*	*Plan travel Distance m*	*Elevation m AHD*	*Travel Angle**	*Notes*
H32	396	Near main access stair	very small	2 and 3	XW and HW Basalt	10.0	0.7	0.3	2.1	2.0	3.5	7.0	52°	
H33	397	Near main access stair	extremely small	1,3 and 8	Residual soil, XW Basalt and landslide debris	4.0	1.3	0.3	1.5	2.0 to 3.0	7.4	9.5	43°	
H34	398	Near main access stair	extremely small	4	Maretimo Clays	1.0	1.0	0.1	<1.0	<1.0	6.5	9.0	45°	
H35	399	Nuns Beach	very small	2 and 3	XW and HW Basalt	7.0	5.0	0.5	10	4.0	14.5	12.5	35°	
H36	399	Nuns Beach	extremely small	6	Limestone	2.0	2.0	0.25	<1.0	1.0		7.0	vertical	
H37	401	Nuns Beach	very small	1,3 and 8	Residual soil, XW Basalt and landslide debris	2.0	3.0	0.4	2.4	2.0 to 3.0		5.5	32°	
H38	402	Nuns Beach	medium	3 and 8	XW basalt and landslide debris	20.0	15.0	1.5	450	5.0		18.0	32°	
H39	403	Nuns Beach	very small	3	XW Basalt	3.0	4.0	0.3	3	1.5	10.0	10..0	37°	
H40	404	West of Nuns Beach Carpark	small to medium	2, 3 and 6	XW and HW Basalt with limestone	15.0	20.0	1.0	112 to 200	5.0	25.0	20.0	35°	
H41	405	Access stairs	very small	2 and 3	XW and HW Basalt	5.0	4.0	0.5	10	3.0 to 4.0		20.0	37	
H42	417	Near timber bridge on GSW	Very small	2	HW Basalt	3.0	3.0	0.5	4.5	6.0 to 8.0	12.0	29.0	45°	
H43	418	Near timber bridge on GSW	extremely small	2	HW Basalt	0.4	0.4	0.4	1	2.0 to 3.0		29.0	50°	
H44	419	Near timber bridge on GSW	extremely small	2	HW Basalt	0.4	0.4	0.4	<1.0	6.0 to 8.0		29.0	50°	
H45	420-422	Whalers Lookout	very small to small	2	HW Basalt	10.0	5.0	0.5	25	5.0 to 10.0	28.0	31.0	47°	
H46	423	Whalers Lookout	extremely small	2	HW Basalt	0.5	0.5	0.5	<1.0	5.0	12.0	30.0	40°	
H47	425-426	Whalers Lookout	very small	1 and 3	Residual basalt and XW Basalt	7.0	5.0	0.3	10.5	5.0 to 10.0	26.0	31.0	49°	
H48	428	Behind Whalers Crt	small	1 and 3	Residual basalt and XW Basalt	10.0 (dia)	10.0 (dia)	1.0	80	5.0 to 10.0	43.5	29.5	33°	
H49	430-431	Behind Whalers Crt	small	1 and 3	Residual basalt and XW Basalt	12.0	5.0	1.0	60	5.0 to 10.0	33.0	29.0	40°	

Note: The estimate of travel angle is based on tan-1((elevation of source – elevation of end point) / plan distance

Table 4 (cont.) Summary of Observed Landslide Hazards In the Initial Study Area

Hazard ID	*GPS Pt*	*Site Description*	*Size*	*Type*	*Materials*	*Width m*	*Length m*	*Depth m*	*Volume m^3*	*Runout m*	*Plan travel Distance m*	*Elevation m AHD*	*Travel Angle**	*Notes*
NH50	527	Top of Wade Street slide	small	1	XW and HW Basalt?	10.0	11.0	1.0??	110??	NA	NA		NA	Uncertain
NH51	570-571	Anderson Point Beach	NA	NA	Bluestone revetment on beach	65.0	2.0	?/	?/	NA	NA		NA	Breach in rock seawall
NH52	530	Path below Whalers Point	extremely small	6	PCL/ Limestone	0.4	0.4	0.4	<0.1	8-10 m	10	14	38°	Travelled to outer path
NH53	531	Path below Whalers Point	very small	7	Flaggy Limestone	5.0	4.0	1.2	24	NA	2-3	9	NA	New vertical crack as yet un-failed
NH54		Whalers Point	extremely small	6	PCL Limestone	0.3	0.3	0.25	<0.05	6 m	17??	13	31°	Travelled to outer path
NH55		Whalers Point	medium	3 and 5	Residual basaltic soil over XW and HW Basalt over Maretimo Clay	23.0	30.0	1.0 to 2.0	1000	Unknown	20? /	20	35° to 40°	Much older slide not previously noted
NH55a		Path below Whalers Point	extremely small	2	XW and HW Basalt	0.1 to 0.25	0.1 to 0.25	0.1 to 0.25	<0.02		45	33	33to 35°	Numerous rockfalls onto path

Table 5 New Hazards observed within Initial Study Area following May 2018 Inspection.

Hazard ID	*GPS Pt*	*Site Description*	*Size*	*Type*	*Materials*	*Width m*	*Length m*	*Depth m*	*Volume m^3*	*Runout m*	*Plan travel Distance m*	*Elevation m AHD*	*Travel Angle**	*Notes*
NH56	533	Steep bank adjacent to Nuns Beach carpark	very small (est)	1	Residual soil derived from limestone and/or volcanics??				<2??	2.0-3.0??	NA	19		No failure yet
NH57	534	Steep bank south of Nuns Beach carpark	very small	1	XW tuff/ basaltic soil??	6.0to 8.0	6.0	0.1	4-6	2.0	10??	10	36°	Talus at base of slope. , site of previous slide??
NH58	535	Steep bank south of Nuns Beach carpark	very small	1	XW tuff/ basaltic soil??	10.0 to 12.0	8.0	0.5	10	2.0	10??	11	42°	Talus at base of slope. , site of previous slide??
NH59	536-537	Steep bank south of Nuns Beach carpark	very small	6a	PCL/ Limestone	0.1 to 0.2	0.1 to 0.2	0.1 to 0.2	<0.01	2.0-3.0?	5 to 6	12	NA	New vertical crack as yet un-failed
NH60	538-540	Steep bank south of Nuns Beach carpark	very small	6	PCL/ Limestone	0.1 to 0.2	0.1 to 0.2	0.1 to 0.2	<0.01	2.0	5 to 6	9	NA	Talus and small cobbles at base of slope
NH61	540=>	Moderately steep bank south of Nuns Beach carpark	Very small	1	Residual soil over limestone??				<2??	2.0 - 3.0?	2 to 4??	6	NA	No immediate signs of instability

Table 6 New and Potential Hazards observed within Extended Study Area (Lee Breakwater North) following May 2018 Inspection.

Hazard ID	*GPS Pt*	*Site Description*	*Size*	*Type*	*Materials*	*Width m*	*Length m*	*Depth m*	*Volume m^3*	*Runout m*	*Plan travel Distance m*	*Elevation m AHD*	*Travel Angle**	*Notes*
NH62	543	Lee Breakwater Rd _south	very small	10	Bluestone blocks over limestone	4.0	4.0 to 5.0	0.2??	3.0 (total)	<2.0		7		Few blocks fallen into buffer
NH63	544-545	Lee Breakwater Rd _south	very small	9	Infill limestone blocks	2.0	1.0	0.75	1.5	<2.0		10		Some fallen blocks have impacted fence
NH64	545-546	Lee Breakwater Rd _south	extremely small	6a	PCL Limestone	0.2 to 0.3	0.2 to 0.3	0.2 to 0.3	<0.03	2.0	2.0	10	63°	To within 0.3m of fence
NH65a	547	Lee Breakwater Rd _south	extremely small	10	Bluestone blocks over limestone	0.3 to 0.4	0.25	0.1	.01	2.0	2.0	10	63°	To just inside fence
NH65b	548	Lee Breakwater Rd _south	Extremely small	10	Bluestone blocks over limestone	0.3 to 0.4	0.25	0.1	.01	2.0	2.0	8	63°	To just inside fence
NH65c	549	Lee Breakwater Rd _south	very small	10	Bluestone blocks over limestone	2.5	1.0	0.75	2	1.5	1.5	8	65°+	To just within fence
NH66	550-551	Lee Breakwater Rd _south	extremely small	6	PCL Limestone	0.2 to 0.3	0.2 to 0.3	0.2 to 0.3	<0.03	1.2	2.0	10	63°	Wider buffer here 1.2 m
NH69	554-556	Lee Breakwater Rd _south	extremely small	6	PCL Limestone	0.2 to 0.3	0.2 to 0.3	0.2 to 0.3	<0.03	0.9	1.5	11	70°+	Narrow buffer here
NH69a	554	Lee Breakwater Rd _south	very small	6	PCL limestone	1.5	3.5	0.25 to 0.3	1.6	0.75	1.0	11	70°+	Narrow buffer here
NH70	556-557	Lee Breakwater Rd _south	extremely small	6	Poor weathered PCL Limestone	0.2	0.2	0.2	<0.008	1.5	1.5	12	63°	Narrow buffer here
NH71	557-560	Lee Breakwater Rd _south	extremely small to very small	6 and 10	Poor weathered PCL Limestone and bluestone above	Variable			<0.01	2.0	2.0	12	60°	Wider buffer here so falls not close to fence
NH71a	558	Lee Breakwater Rd _south	Very small	6	Poor weathered PCL Limestone	8.0	1.0	1.0	8.0	2.2	2.5	12	63°	Wide buffer here
NH72	560-559	Lee Breakwater Rd _south	Extremely small to very small	6	Poor weathered PCL Limestone	Variable			<0.01	2.0	2.0	11	60°	Wider buffer here so falls not close to fence

Table 7 New Hazards observed within Extended Study Area at Lee Breakwater Road South following May 2018 Inspection.

7.4.2 Discussion of Observations

Based on a review of the past and recently observed failure mechanisms, ten (10) general types of landslide hazard or modes of failures have now been identified and noted within the extended study area and are presented in Table 8. The table also summaries the number of failures in each category observed within the various study sub areas.

Hazard type ID	***Description***	***Number of existing and new failures observed in each study sub area****		
		Anderson Pt to Nuns Beach	Lee Breakwater Rd North	Lee Breakwater Rd South
Type1	Slide (generally rotational) failure in Residual Basaltic soils (clay)	10	4	
Type 2	Rockfall in Highly Weathered (HW) Basalt	21		
Type 3	Slide (partly rotational to translational) in Extremely Weathered (XW) Basalt	29		
Type 4	Slide (rotational) in Maretimo Clays only	5		
Type 5	Complex slide (partly rotational with more translational base) through XW basalt and Maretimo Clays	5		
Type 6	Rockfall (topple and slabbing failures) in Limestone	5	2	8
Type 7	Shallow surficial slide (translational) in sandy Limestone	3		
Type 8	Slide (generally rotational) in previous landslide debris materials	5		
Type 9	Rockfall in isolated limestones boulders			1
Type 10	Fall of bluestone blocks over Limestone			5

**Note the number of total failures exceeds number of hazard sites as multiple failures types were noted at some locations.*

Table 8 General hazard types and numbers of observed occurrences within the various study sub areas.

As such, it is clear that the majority of the failures within the first two study sub areas occurred within the extremely weathered and highly weathered basalts which is in line with the previous observations of landslide hazards within the general region as described in Section 5.

The main failure mode in the southern Lee Breakwater Road section is associated with falls and weathering of the Port Campbell Limestone which then initiates falls of the bluestone blocks placed directly above the PCL.

Landslide volumes were also noted to vary significantly with volume ranges spanning from *extremely small to moderate* as defined in the table below. The number of occurrences in each category for the study sub area is summarised in Table 9 below.

Travel distances of the landslide hazard is an important factor to consider when assessing the consequences associated with a particular hazard. Information provided in Table 10 relates specifically to the distance travelled beyond the base of the cliff as this is important in assessing impact to paths and users on the lower levels of the site below cliff lines.

Note: Overall travel distance has also been estimated for each hazard and was used in an evaluation of the travel angle defined as $\tan^{-1}$ (the plan distance travelled divided by the height differential of travel).

Relative size term	***Volume Range m3***	***Typical dimensions (width x length x depth) m***	***Number of failures observed in this range***		
			Anderson Pt to Nuns Beach	Lee Breakwater Rd North	Lee Breakwater Rd South
Extremely small	<2	3 x 1 x0.3	23	2	8
Very small	2 to 10	4 x 2 x 0.5	17	4	5
Very small to small	10 to 30	6 x 5 x 1	4		
Small	30 to 150	7 x 6 x 2	9		
Small to medium	150 to 300	10 x 10 x 2	1		
Medium	300 to 3000	20 x 30 x 4	4		
Large	>3000	40 x 80 x8	0		

Table 9 Definition of landslide sizes used in this study and numbers of observed occurrences within each of the study sub areas

Travel distance of hazards beyond the base of the cliff (m)	***Number of failures observed in this range***		
	Anderson Pt to Nuns Beach	Lee Breakwater Road North	Lee Breakwater Rd South
<1.0 m	7		2
1.0 to 2.0	9	3	10
2.0 to 3.0	12	3	1
3.0 to 5.0	12		
5.0 to 10.0	13		

Table 10 Travel distance beyond the base of the cliff and numbers of observed occurrences within each of the study sub areas

Although there are a numerous combinations of hazard type, volumes and travel distance and it is difficult to formulate hard and fast rules for these combinations, the following very general relationships were noted for the study site:

- ***Extremely small*** volume slides tended to involve only saturated Maretimo Clays with very little runout and/or single isolated rockfalls which could however have very significant runout.
- ***Very small*** volume failures tended to be varied and can include slides within XW Basalt, rockfalls in either Limestone or HW Basalt and/or slides within residual basaltic soils and past landslide debris. Runout distance was variable and is very dependent on material type, degree of saturation at the time of failure and how high in the profile the failures occurred.
- Rockfalls from the Port Campbell limestone vary significantly in range of size with most being **extremely small to very small** (e.g. Lee Breakwater South) but then occasionally and much less frequently, some much larger volume rockfall or topple
- ***Small*** volume failures included some of the more significant XW basalt slides and many of the residual basalt soil slides which may be progressive or retrogressive failures at the sites of previous failures.
- ***Small to Medium and Medium*** volume failures generally included deeper more complex slide mechanisms involving multiple soil types with significant runout.

It is also evident that:

- Rockfalls in the HW Basalts fail from high up in the profile, travel rapidly and cover significant distances and pose significant threats to users of the path and beach below.
- Rockfalls in the Port Campbell limestone tend to be at lower elevations and travel less distance from the cliff face as a result (e.g. Lee Breakwater South)

- Failures involving the placed bluestone blocks are initiated due to weathering of the PCL underneath the bluestone as well as intervention of roots within the rows of blocks from vegetation and trees planted above.
- Small to Medium and Medium volume slides especially in XW Basalt often include some failure through the underlying Maretimo Clays and can have considerable runout distances with debris cascading over the near vertical limestones below.
- Slides in residual basaltic soils transition into flows indicating significant saturation during failure and highlighting the importance of transient surface drainage aspects as well as the importance of longer term subsurface groundwater conditions.

Note: Whilst the above generalisations are useful in understanding trends within the study site, it is recommended that any detailed assessment and /or discussion of a specific hazard should refer back to the individual hazard identification sheet and the specific site conditions for that hazard.

8. Re-Assessment of Risks

The previous risk assessment was conducted in general accordance with the principles of the Australian Geomechanics Society's "Landslide Risk Management Concepts and Guidelines" (AGS 2007).The previous methodology applied to the risk assessment process is described in Appendix G.

This latest re-assessment of risk for previously assessed hazards and assessment of risk for new hazards has been also conducted using the AGS2007 process but in addition has been correlated against the current principles and intent of the DELWP Risk Management Guidelines (Zeeher and Khoo, 2017).

Whilst general principles for these two risk approaches are similar, it is noted that there are subtle variations and the current assessment makes note of such differences wherever appropriate.

IMPORTANT NOTE: A number of important considerations in undertaking this risk assessment must be clearly stated and clarified for the overall context of the risk assessment to be fully understood. Such considerations are discussed in the following sections:

8.1 Establishing the Context of the Assessment

Clear definition of the context and scope of a risk assessment is a very important step in understanding the constraints and limitations of the assessment.

The initial basic stated aim of this current study as per the project brief is to "*re assess risk for existing hazards"* and by inference to apply the same risk assessment process to new hazards.

Following discussion with DELWP and GSC on the 16th July 2018 at a risk workshop for the project, the following contextual considerations as they apply to this project were also confirmed:

- DELWP's risk management framework applies and ensures key risks are effectively identified and responded to in a manner that is appropriate to the:
    - nature of the risks to which the department is exposed
    - nature of the inter-agency and state significant risks where the department is a lead or contributing agency
    - ability to accept and/or manage risks
    - resources available to manage risks
    - department's culture (as per the DELWP Risk Management Guidelines).
- DELWP is identified as the owner of risk on Crown Land
- GSC as a Committee of Management has an inter-agency role.
- DELWP recognise that the hazards on the Crown Land where inter-agency risks have been identified, must be recorded in the appropriate Risk Management register as operational risks as per the (DELWP) Risk Management Guidelines.

- The key objective for the management for risks at this site is deemed to be reflective of the stated DELWP risk category of *"Public Safety, Liability and Insurance"* and dealing with consequences under the category of *"Well-being and Safety"*[1]
- DELWP and GSC agree that access to Clifton Beach and the continuing operation of the community funded Anderson Point stairs is more than likely a non-negotiable for the Community.
- By providing access to Clifton Beach, DELWP and GSC acknowledge there is likely a strong public sentiment in continuing access along Clifton Beach, past Whalers Point and onto Nuns Beach to allow a walking 'loop/route' to be maintained that utilises paths along the beach and along the top of cliff which are linked by stairs at Anderson Point and Nuns Beach.

In relation to the methodology to ensure public safety, reference to the DELWP Risk Management Guidelines suggests the following:

- Although the DELWP guidelines generally provide guidance on the basis of a qualitative approach, they do acknowledge the use of quantitative approaches. As such, the risk assessment has been carried out as a qualitative assessment for risk to infrastructure and a quantitative assessment for risk to life which is in accordance with standard risk practice adopted in the AGS 2007 guidelines. Generally no assessment for impact to the environment has been included in this assessment.
- Evaluation of risk levels has been undertaken (where possible) against DELWP's Risk Appetite statement (see Table 8 on page 28 of the DELWP Risk Management Guidelines). Where quantitative risk assessment has been used to assess risk to life, the initial risk evaluation has been undertaken using recommended criteria published in AGS2007 with additional comment how these might be interpreted in view of the DEWLP qualitative criteria

8.2 Elements at Risk and Public Usage

The key element at risk assessed in this risk assessment includes (but is not limited to) public users of the areas both at the top and the bottom of the Portland cliffs. In particular, this includes walkers along the beach from Anderson Point to Nuns Beach and pedestrians on the footpath along the southern section of the Lee Breakwater Road.

IMPORTANT NOTE: No detailed information was available on usage rates on the beach level path or the cliff top walk. As a result, assumptions have been made on the basis of general comments on usage made by GSC representatives at an initial site meeting in 2013. Further clarification was sought from GSC to firm up these estimates for this current reassessment of risk however no other data of actual usage was available at the time of this current study.

As such, the same assumptions of usage rates and exposure times to hazards have been used although it is understood that GSC are now working towards confirming and clarifying usage numbers It must be recognised that modifications to these assumptions would change the estimated levels of quantitative risk and other conclusions regarding risk evaluation that may be arrived at.

8.3 Hazard Identification (Modes of Failure)

Refer to failure modes as described in Tables 4 to 7 in Section .7.2.

8.4 Probability of Hazard Occurrence

One of the most important components of the risk assessment is the estimation of likelihood of the event or an annual probability of occurrence. This is the most difficult part of the process and often requires expert judgement based on the available information.

8.4.1 Comparative observations and change over time

To assist with the assessment of likelihood of occurrence of existing hazards and how such hazards have continued to develop and evolve over time, a detailed temporal comparison of all the previous hazards was conducted.

Observations of the hazards as the existed in September 2013 were compared with how they now appeared during the current inspection in May 2018. Details of this comparisons are in Appendix H and have been used in developing judgement on future likelihood especially in light of climate conditions and rainfall in the intervening period between inspections (see next section for discussion on rainfall).

8.4.2 Rainfall analysis and its use in assessment of likelihood

The previous risk assessment established a strong link between heavy and prolonged rainfall with previous landslide events and in many cases an analysis of rainfall can be used to assist the assessment of hazard likelihood

Following on from the initial preliminary assessment of rainfall in the 2013 study, further review and analysis of rainfall for Portland was conducted to assess the conditions under which the current hazards has occurred and to review the potential triggers for future occurrences. Analysis of historical rainfall is contained in Appendix I.

It was previously noted that the rainfall in 2013, both on a daily and cumulative basis, was extreme when compared with historical records. In fact, the highest cumulative totals on record for 14 day, 30 day, 60 day and 90 day periods for the Bureau of Meteorology (BOM) weather station at Portland (Cashmore Airport ID 090171) were all recorded in August 2013.

Long term cumulative totals are an important proxy for regional groundwater levels and high totals have been previously observed to mirror high groundwater levels (PB 2009).

The current analysis of rainfall has also confirmed similar levels of antecedent rainfall were also recorded at the time of the 1974 Hanlon Parade landslide and prior to the 2007 Wade Street landslide-which are two of the much larger landslides to have occurred in the region.

In addition to the high antecedent rainfall observed in August 2013, it was also noted that the daily rainfall total of 61.0 mm on the 14th of August ranked in the top 99.5% percentile of all daily readings and is possibly of the order of a 1 in 50 to 1 in 100 year event

Hence the records suggest there is a combination of both antecedent rainfall plus an initiating or triggering event that is needed to produce large scale landsliding

This landslide inventory notes 3 significant events in the past 50 years or so over a coastline of approximately 3.0 km. So whilst high antecedent rainfall totals and extreme daily events are seen as

infrequent events, the combination of these two circumstances can and has occurred a number of times in the past 100 years or so.

A review of more recent climate conditions between 2013 and 2018 (the intervening period between site inspections and risk assessments) noted a number of significant (i.e. >90% percentile exceedance) longer term cumulative daily rainfall totals (i.e. 30, 60, 90 and 120 day running totals), but only a few > 98 % percentile exceedances and almost no > 99% percentile exceedances which were seen during the 2007 and 2013 Portland landslide events at Wade Street and on the Portland cliffs respectively.

As a result, this suggests that the ongoing small rockfall events noted as continuing between 2014 and 2018 are probably more likely to be associated with the 90% percentile cumulative rainfall event (plus it is postulated in combination with a significant daily rainfall event) whilst it takes a much larger regional cumulative rainfall event (say >98% percentile exceedance plus again most likely a significant daily triggering event) to initiate the larger type slides.

Hence the combination of long term saturation of the soils through high ongoing seasonal rainfall (say 1 in 20 to 1 in 50 year type events) plus a significant triggering event such as a 1 in 50 year daily rainfall event has been assessed as likely conditions for future larger failures. Smaller rockfall events seems to be associated with somewhat more frequent events.

As a result, likelihood for future large failure used in this risk analysis has been taken to be *Likely* to *Possible* (between 1x 10^{-3} and 1 x 10^{-2}) whilst small rockfalls and some smaller surficial slides are taken to be at least *Likely* (indicative annual probability of 1 x 10^{-2} or 1 in 100) as per the definitions used in the AGS (2007) landslide risk guidelines.

Some individual adjustments have been made to accommodate specific hazard circumstances on the basis of observations over the past 5 years and expert judgement.

8.5 Consequence Considerations

Refer to ASMG 2013 for discussion of assignment of consequence as they relate to risk to life and risk to infrastructure as per the AGS 2007 guidelines.

The DELWP Risk Management Guidelines indicate that consequence is defined as *"the outcome of an event affecting objectives*" and these guidelines include consequence categories relating to:

- Financial
- Environment and Cultural heritage
- Well-being and safety
- People and Culture
- Political/Reputational
- Legal
- Service and Program Delivery

However the initial definition of project objectives has constrained the risk assessment and as such the main element for this risk assessment has been generally limited to "public safety and well-being".

IMPORTANT NOTE: It is however noted that other aspects of consequence may also need to be assessed in the future depending on stakeholder values and aspirations and it is acknowledged that issues such as maintaining and/or restricting public access along the beach may invoke other consequences associated with political and reputational status.

8.6 Estimation of Risk

Risk is defined as the product of likelihood and consequence such that:

Risk = Likelihood x Consequence

As was the case associated with the original risk assessment, an initial qualitative assessment of the hazards was undertaken to reduce the amount of detailed risk assessment required.

Based on the premise that hazards with limited volume or limited runout would have little to no potential for impact on the considered elements of risk, the 78 hazards were reduced to 25 for more detailed assessment.

Following this initial assessment of “more significant” hazards, a determination of risk due to geological hazards was completed for the full extended study site based on a consideration of the elements at risk, the possible hazards, their potential likelihood of occurrence and the consequence of each hazard for various elements at risk.

Some of these assessments involved re-assessment of risk for previous hazards

As previously indicated, risks have been estimated for both infrastructure and for users of the site. A qualitative assessment has been conducted for risk to infrastructure and a quantitative assessment has been conducted for risk to life in accordance with the AGS (2000 and 2007) guidelines.

A standard template was set up to carry out the preliminary risk assessment for the 25 “more significant” landslide hazard locations identified across the study site. Completed preliminary risk assessment templates are included in Appendix J.

IMPORTANT NOTE: Whilst the qualitative approach for infrastructure is very similar to that adopted in the DELWP Risk Management Guidelines, the quantitative approach has no equivalent in the DELWP guidelines. The next sections discusses ways the AGS and DELWP systems can be aligned for risk evaluation.

8.7 Evaluation of Risk

Having calculated the level of risk the next process in the assessment is to gauge how important or significant is the level of risk. This is done through comparison with established risk criteria.

Risk evaluation or acceptance criteria as per the DELWP guideline and the AGS2007 guidelines are usually presented as the outcome of a matrix combining likelihood and consequence

The form of these two evaluation matrices is indicated in the Tables 11 and 12 below.

By reviewing the overall form of the matrices it has been determined that the different risk designations can be generally matched up as follows

- DELWP High is the equivalent of AGS Very High
- DELWP Significant is the equivalent of AGS High
- DELWP Medium is the equivalent of AGS Moderate
- DELWP Low is the equivalent of a combination AGS Low and Very Low

An AGS risk level of **Moderate** is described as a "Tolerable Risk" level whereby tolerable risk is described as "*A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negotiable and needing to be kept under review and reduced further if possible".*

The equivalent DELWP risk level of Medium is described as one that falls within DELWP risk appetite. It may be managed or accepted without further treatment provided that at least on a 6 monthly basis the risk is appropriately monitored (by the risk owner) with re-evaluation undertaken based on factors that may increase consequence or likelihood.

As such, it is concluded that the two levels of risk are also generally equivalent in their meaning.

DELWP	***Consequence***					
Likelihood		Negligible (-1)	Minor (-2)	Moderate (-3)	Major (-4)	Extreme (-5)
	Almost Certain (5)	Medium	Significant	High	High	High
	Likely (4)	Medium	Medium	Significant	High	High
	Possible (3)	Low	Medium	Medium	Significant	High
	Unlikely (2)	Low	Low	Medium	Medium	Significant
	Rare (1)	Low	Low	Low	Medium	Significant

Table 11 Likelihood- Consequence risk Matrix as per DELWP Risk Management Guidelines (2017)

AGS	***Consequence***					
Likelihood		Insignificant (5)	Minor (4)	Medium (3)	Major (2)	Catastrophic (1)
	Almost Certain (A)	Moderate	High	Very High	Very High	Very High
	Likely (B)	Low	Moderate	High	Very High	Very High
	Possible (C)	Very Low	Moderate	Moderate	High	Very High
	Unlikely (D)	Very Low	Low	Low	Medium	High
	Rare (E)	Very Low	Very Low	Low	Low	Moderate

Table 12 Likelihood- Consequence risk Matrix as per AGS Landslide Risk Management Guidelines (2007)

For quantitative assessment the AGS (2000 and 2007) guidelines suggest the following criteria for slopes with existing landslide hazards are as follows:

- Tolerable risk for loss of life for person most at risk of 10^{-5}
- Acceptable risk for loss of life for person most at risk of 10^{-6}

Whilst the DELWP guidelines do not provide any quantitative criteria, by inference the **Medium** risk, deemed to be tolerable, would be equivalent to a quantitative risk of 10^{-5} for this particular case which takes account that these slopes have been subjected to previously landslide activity.

Hence it is presumed that 10^{-5} is an equivalent to a DELWP "**Medium"** risk and that quantitative risk levels greater than 10^{-5} would initially fall in the DELWP "**Significant"** risk category and if they far exceed 10^{-5} would fall in a DELWP **"High**" risk category.

The results of the risk assessment have been summarised and collated in tabular format for both risk to life and risk to infrastructure and are presented in Tables 13 and 14 and are summarised in the next section.

8.8 Summary of Risk Levels

Using the DELWP guidelines as the guiding protocol for risk assessment and evaluation at this site, it is evident that a number of combinations of hazards and exposed elements at risk fall into **High Risk** levels. These include:

- Users of the Anderson Point stairs due to shallow slide (Hazard H1a) below lower landing
- Walkers along path below Whalers Point due to rockfalls from upper section of cliff source from Hazard H45 and H47 and collectively designated as Hazard H55a
- Walkers along the path below Whalers Point due to isolated rockfall from Port Campbell Limestone and the Werrikoo flaggy limestone bed from Hazard H52 and right on the point from Hazard H54

In addition a number of combinations of hazards and exposed elements at risk fall into **Significant Risk** levels and these include:

- Walkers on the path below slides above the PCL from hazards H13, H16 and H55 at Whalers Point and from Hazard H23 on the Nuns Beach section.
- The Great South West Walk (GSWW) trail itself from ongoing retrogression at the cliff top from Hazards H48 and H49
- The outer fence at the Whalers Point lookout from retrogression from Hazards H45 and H47

A number of hazard and elements at risk combinations present as **Medium to Significant Risk** and these include

- Walkers on the path below Whalers Point due to potential cliff face collapse in the PCL from Hazard H53
- Pedestrian's on the footpath on the southern section of the Lee Breakwater Road due to rockfall from PCL and /or collapse of bluestone blocks placed directly above the PCL

Other combinations fall into the **Medium Risk** level and include;

- Walkers on the beach path at Clifton Beach due to a soil slide from the upper cliff profile at Hazard H5
- Users of the main beach access stairs at Nuns Beach due to Hazard H41
- Occupants of vehicles using the northern Lee Breakwater Road from slides in XW basalts and Tuffs designated as Hazards H57 and H58
- The fencing along the southern Lee Breakwater Road

All other combinations of risk and hazard fall into the **Low Risk** category

Discussion of remedial treatments and management actions to cater for these risk and to reduce them to tolerable and/or acceptable levels so as to achieve the project objectives is contained in the next section.

Hazard	*Location*	*Type Hazard*	*Element at Risk for Life Considerations*	*Estimated risk to Life AGS 2007*	*Recommendation against AGS 2007 Criteria for Existing landslide conditions*	*Postulated Equivalent DELWP risk level*	*Element at risk for infrastructure Considerations*	*Estimated risk to Infrastructure AGS 2007*	*Recommendation against AGS 2007 Criteria*	*Postulated Equivalent DELWP risk level*
H1a	Anderson Point	Slide in HW and XW basalt	Users of Anderson point stairs	3.5 x 10--3	**Unacceptable**	**HIGH**	Stairs	Moderate to High	**Tolerable to Unacceptable**	**SIGNIFICANT**
H4 from H49	Clifton Beach	Slide in soil and rock	Users of path on beach	1.5 x 10-5	**Tolerable**	**MEDIUM**				
H5 from H48	Clifton Beach	Slide in soil and rock	Users of path on beach	0.0	**Acceptable**	**LOW**				
H13	Whalers Point	Complex slide in soil, rock and clay	Users of path	2.6 x 10-4	**Unacceptable**	**SIGNIFICANT**				
H16	Whalers Point	Slide in HW and XW basalt	Users of path	1.6 x 10-4	**Unacceptable**	**SIGNIFICANT**				
H18	Whalers Point	Rockfall in PCL limestone	Users of path	6.2 x 10-6	**Acceptable**	**LOW**				
H23	Cliffs below caravan park	Complex slide in soil and rock	Users of path	6.2 x 10-4	**Unacceptable**	**SIGNIFICANT**				
H35	Nuns beach	Slide in HW and XW basalt	Users of path	1.4 x 10-6	**Acceptable**	**LOW**				
H38	Nuns Beach	Slide in soil, XW basalt and landslide debris	Users of path	2.1 x 10-6	**Acceptable**	**LOW**				
H40 (Remediated)	Nuns Beach	Complex slide in soil, basalt and limestone	Users of reserve below	1.2 x 10-6	**Acceptable**	**LOW**				
H41	Nuns Beach access stairs	Slide in XW and HW basalt	Users of the stairs	3.3 x 10-5	**Barely Tolerable**	**MEDIUM**	Stairs	Moderate	Tolerable	**MEDIUM**
H45 addressing H19 and H21	Whalers Point	Rockfalls from XW and HW Basalt	Users of path	1.5 x 10-4 to 3.8 x 10-3	**Unacceptable**	**HIGH**				
H47 addressing H55a.	Whalers Point	Rockfall in HW and XW basalt	Users of the path	4.9 x 10-3to 2.2 x 10-3	**Unacceptable**	**HIGH**				

Table13 Re-assessment of Risks in Original Study Area following Current Inspection in May 2018

Hazard	*Location*	*Type Hazard*	*Element at Risk for Life Considerations*	*Estimated risk to Life AGS 2007*	*Recommendation against AGS 2007 Criteria for Existing landslide conditions*	*Postulated Equivalent DELWP risk level*	*Element at risk for infrastructure Considerations*	*Estimated risk to Infrastructure AGS 2007*	*Recommendation against AGS 2007 Criteria*	*Postulated Equivalent DELWP risk level*
H47 (with current barrier)	Whalers Point	Rockfall in HW and XW basalt	Observers at Lookout	0.0 with exclusion zone in place	**Acceptable**	**LOW**	Fence	Moderate to High	Tolerable to Unacceptable	**SIGNIFICANT**
H48 (with current barrier)	Clifton Crt	Slide in soil and rock	Walkers at cliff edge (GSWW)	0.0 with exclusion zone in place	**Acceptable**	**LOW**	Public reserve/path	Moderate to High	**Tolerable to Unacceptable**	**SIGNIFICANT**
H49 (with current barrier)	Clifton Crt	Slide in soil and rock	Walkers at cliff edge (GSWW)	0.0 with exclusion zone in place	**Acceptable**	**LOW**	Public reserve/path	High	**Unacceptable**	**SIGNIFICANT**
H52	Whalers Point	Isolated rockfall from PCL	Users of the path	4.8 x 10-3	**Unacceptable**	**HIGH**				
H53	Whalers Point	Vertical Collapse in PCL	Users of the path	5.0 x 10-5	**Barely Tolerable to Unacceptable**	**MEDIUM to SIGNIFICANT**				
H54	Whalers Point	Rockfall in flaggy limestone	Users of the path	4.8 x 10-3	**Unacceptable**	**HIGH**				
H55	Whalers Point	Complex slide in soil rock and clay	Users of the path	7.7x 10-5	**Unacceptable**	**SIGNIFICANT**				

Table13 (cont.) Re-assessment of Risks in Original Study Area following Current Inspection in May 2018

Hazard	*Location*	*Type Hazard*	*Element at Risk for Life Considerations*	*Estimated risk to Life AGS 2007*	*Recommendation against AGS 2007 Criteria for Existing Slope conditions*	*Postulated Equivalent DELWP risk level*	*Element at risk for infrastructure Considerations*	*Estimated risk to Infrastructure AGS 2007*	*Recommendation against AGS 2007 Criteria*	*Postulated Equivalent DELWP risk level*
H57	South of Nuns Beach carpark	Slide in soil/ XW tuff/basalt	Occupant of vehicle on road	5.6 x 10-6	Acceptable to Tolerable	**MEDIUM**				
H58	South of Nuns Beach carpark	Slide in soil/ XW tuff/basalt	Occupant of vehicle on road	9.8 x 10-6	Tolerable	**MEDIUM**				
H68	Lee Breakwater Road	Fall of bluestone blocks	Pedestrians on path	1.9 x 10-4	Barely Tolerable to **Unacceptable**	**MEDIUM** to SIGNIFICANT	Fence and path	Low to moderate	Acceptable to Tolerable	**MEDIUM**
H69	Lee Breakwater Road	Fall of bluestone blocks	Pedestrians on path	1.9 x 10-4	Barely Tolerable to **Unacceptable**	**MEDIUM** to SIGNIFICANT	Fence and path	Low to moderate	Acceptable to Tolerable	**MEDIUM**
H70	Lee Breakwater Road	Fall of bluestone blocks	Pedestrians on path	1.9 x 10-4	Barely Tolerable to **Unacceptable**	**MEDIUM** to SIGNIFICANT	Fence	Low to moderate	Acceptable to Tolerable	**MEDIUM**

Table 14 Assessment of Risks in New study Areas following current inspection in May 2018

9. Discussion on Risk Treatments and Mitigation

Management of risk and the need for both risk mitigation (to reduce levels of risk) and risk treatments (to manage levels of risk) can be related back to Table 8 in the DELWP Risk Management Guidelines which relates to treatment and report requirements. As a brief summary of this table it is stated that:

- **HIGH** risk falls outside DELWP's risk appetite and would require active monitoring, risk treatments, management options that reduce risks to as low as reasonably possible (ALARP) and significant reporting activities
- **SIGNIFICANT** risks may fall outside DELWP's risk appetite and would require a risk treatment plan, management options to ALARP principles and regular monitoring and reporting
- **MEDIUM** risk falls within DELWP's risk appetite and may be managed without further treatment but still require regular monitoring on a 6 monthly basis
- **LOW** risk falls well within DELWP's risk appetite and would still require appropriate levels of monitoring and reporting

Previous detailed discussion on possible risk treatment options was provided in the original ASMG report in 2013 and with an updated review of these options provided in a subsequent ASMG report to DELWP in 2014.

Reassessment of risks and clarification of DEWLP's and GSC's objectives for the site now require further refinement of risk treatments and management actions.

However, final adoption of risk mitigation plans and treatments is, to a significant degree, based on DELWP's and GSC's own organisational interpretation of the DELWP guidelines to ensure public safety and well-being whilst also considering other factors which might include (but not be limited to) financial, legal, political and/or reputational risk.

As such a further phase of discussion and direction with both DELWP and GSC before finalisation and choice of preferred risk treatment options can be undertaken.

However, on the basis of the stated objectives of the current project with respect to public access and safety, the significant previous work completed on various remedial options and the use of the DELWP guidelines as an overall general guide to potential organisational position of risk, ASMG has collated possible remedial and management options for consideration by DELWP and GSC (see Table 15).

IMPORTANT NOTE: Costs estimates are preliminary only and provided as broad guidance only. It is highly recommended that any budget decisions must be based on more detailed cost determinations.

9.1 Priority and staging of works

As discussed final details of remedial works is still uncertain and is expected to include a number of considerations including financial.

The initial priority for works is recommended to tackle areas that retain some level of public access. Then other areas should be prioritised based on level or significance of risk.

As a result the following recommendations for staging of works is provided for consideration by DELWP and GSC as follows:

Areas with open public access.

1. Hazard H1a- Possible relocation of stairs at Anderson Point
2. Hazard H41 –Retaining wall at Nuns Beach access stairs
3. Hazards H68-H70 – Possible relocation of pedestrian path on southern section of Lee Breakwater Road.

Areas currently with restricted/closed public access:

4. Hazard H47- stabilisation of upper cliff face below Whalers Point and relocation of lookout fencing
5. Hazard H45- stabilisation of upper cliff face below Whalers Point and relocation of lookout fencing
6. Hazard H54- stabilisation of lower cliff face at Whalers Point
7. Hazard H52 - stabilisation of lower cliff face in PCL, Clifton Beach.
8. Hazard H13 – stabilisation of mid-level cliff face below Whalers Point
9. Hazard H16 – stabilisation of mid-level cliff face below Whalers Point
10. Hazard H23- stabilisation and/or possible path relocation on Nuns Beach
11. Hazard H53- stabilisation /monitoring of lower cliff face in PCL Clifton Beach

Then finally although hazards are being managed thru temporary exclusion zones and risk are low for the public, the following hazards along the Great South West Walk should also be addressed;

12. Hazard H48- stabilisation of head of gully with retaining wall and permanent barriers
13. Hazard H49- stabilisation of head of gully with retaining wall and permanent barriers

Note current formal closure of the walking path between Clifton Beach and Nuns Beach via Whalers Point should remain in place until remedial works have been implemented and other management actions and monitoring programs enacted.

Hazard Id	*Location*	*Type and Size*	*Key elements at risk*	*Estimated Equivalent DELWP risk to Life*	*Estimated Equivalent DELWP risk to Infrastructure*	*Existing Management*	*Possible Management Required*	*Possible risk treatments required based on the main project objectives*	*Preliminary Estimated costs for this hazard*	*Accountability*	*Reporting required*
H1a	Anderson Pt	Slide in HW and XW basalt Small (120m^3)	Users of stairs	**HIGH**	**SIGNIFICANT**	Open	Currently requires immediate weekly inspections / monitoring and closure if the next iteration of the slide (Hazard H1a) becomes evident	Relocate stairs onto stabilised Wade Street landslide slopes to ensure long term access to Clifton Beach Alternatively Re-profile, light soil nail and mesh and monitor	$50K (estimate from GSC) $80K-$90KK	Top level of management	Reported quarterly
H4 from H49	Behind Whalers Crt	Slides in soil and rock Small (85 m^3)	Users of beach path	**MEDIUM**		Path closed	Monitored and re-evaluated on 6 monthly basis This location not required to be closed	Drainage assessment for area above recommended as part of ALARP principles but no other specific treatments	$35-40KK	Senior management	Reporting 6 monthly
H5 from H48	Behind Whalers Crt	Slides in soil and rock Small (75 m^3)	Users of beach path	**LOW**		Path closed	Include in overall annual review This location not required to be closed	Drainage assessment for area above recommended as part of ALARP principles but no other specific treatments	Incorporated with H4	Project manager	Annual
H13 (see Fig 10)	Below Lighthouse Crt	Complex Slide in soil rock and clay Medium (600 m^3)	Users of path below	**SIGNIFICANT**		Closure of path	Maintain closure of path until remedial works undertaken Maintain warning and hazard signage at entry points to this section Regularly inspected and reviewed on quarterly basis	Stabilisation of H13 (slide immediately above PCL) required to allow ongoing access on walking path below Whalers Point. May include some scaling of unstable rocks , some re-profiling of the face and soil nails and mesh to control surficial slides If soil nail and mesh is not visually amenable, alternative could be rockfall netting to contain rocks and some of any future slide but mot generally as effective as soil nail and mesh. Works only to be carried out after remediation to H47 above	$60-$65K	Senior management	Reported quarterly

Table 15 Summary of key hazards, risks, management, proposed risk treatments and preliminary cost estimates

Hazard Id	*Location*	*Type*	*Key elements at risk*	*Estimated Equivalent DELWP risk to Life*	*Estimated Equivalent DELWP risk to Infrastructure*	*Existing Management*	*Possible Management Required*	*Possible risk treatments required based on the main project objectives*	*Preliminary Estimated costs for this hazard*	*Accountability*	*Reporting required*
H16 (see Fig 10)	Below Whalers Pt Lookout	Slide in HW and XW basalt Small (30 m^3)	Users of path below	SIGNIFICANT		Closure of path	Maintain closure of path until remedial works undertaken Maintain warning and hazard signage at entry points to this section Regularly inspected and reviewed on quarterly basis	Stabilisation of H16 (slide immediately above PCL) required to allow ongoing access along walking path below Whalers Point May include some scaling of unstable rocks , some re-profiling of the face and soil nails and mesh to control surficial slides If soil nail and mesh is not visually amenable, alternative could eb rockfall netting to contain rocks and some of any future slide but mot generally as effective as soil nail and mesh Works only to be carried out after stabilisation of both Hazard H45 and H47 above.	$50-$55K	Senior management	Reported quarterly
H18	Below Whalers Pt Lookout	Rockfall in limestone Very Small (6 m^3)	Users of path below	LOW		Closure of path	Include in overall annual review .This location not required to be currently closed	No specific treatment required	NA	Project manager	Annual
H23 (see Fig 10)	Cliffs below Caravan Park	Complex Slide in soil rock and clay Small (25 m^3)	Users of path below	SIGNIFICANT		Closure of path	Maintain closure of path until remedial works undertaken Maintain warning and hazard signage Regularly inspected and reviewed on quarterly basis	Stabilisation required at Hazard H23 to allow access on existing path alignment. These works may involve rock scaling, selected tree removal, re profiling and rockfall netting .Alternative option is to re-locate walking path as far away from this hazard as possible to the inner side of the seawall and construct a rockfall/slide barrier similar to Nuns Beach slide in combination with bollards. Removal of trees on edge and some re-profiling would also be expected.	$15-20K	Senior management	Reported quarterly

Table 15(cont.) Summary of key hazards, risks, management, proposed risk treatments and preliminary cost estimates

Hazard Id	*Location*	*Type*	*Key elements at risk*	*Estimated Equivalent DELWP risk to Life*	*Estimated Equivalent DELWP risk to Infrastructure*	*Existing Management*	*Possible Management Required*	*Possible risk treatments required based on the main project objectives*	*Preliminary Estimated costs for this hazard*	*Accountability*	*Reporting required*
H35	Nuns Beach	Slide in HW and XW basalt Very Small ($10m^3$)	Users of path below	**LOW**		Open	Include in overall annual review Remain open to Public	No specific treatment required	NA	Project manager	Annual
H38	Nuns Beach	Slide in soil, XW basalt and landslide debris. Medium ($450m^3$)	Walkers at top of cliff and below	**LOW**		Open	Include in overall annual review Remain open to Public	No specific treatment required	NA	Project manager	Annual
H40	West of Nuns Beach carpark	Complex slide in soil, basalt and limestone. Medium (Up to 200 m^3)	Walkers at top of cliff and users of reserve	**LOW**		Open	But include in annual inspection	Site remediated	NA	Project manager	Annual
H41	Nuns Beach access stairs	Slide in XW and HW basalt Very Small ($10m^3$)	Stairs and Users of the stairs	**MEDIUM**		Open	Monitored and re-evaluated on 6 monthly basis. Also undertake inspection after heavy rainfall This location not required to be closed	Stabilisation recommended at hazard H41 to ensure long term integrity of stairs and foundations. Install retaining wall to provide support to footings Assess and review drainage above the stairs and assess if new provisions are required to prevent flows into this area.	$15- $20K	Senior management	Reporting 6 monthly

Table 15(cont.) Summary of key hazards, risks, management, proposed risk treatments and preliminary cost estimates

Hazard Id	*Location*	*Type*	*Key elements at risk*	*Estimated Equivalent DELWP risk to Life*	*Estimated Equivalent DELWP risk to Infrastructure*	*Existing Management*	*Possible Management Required*	*Possible risk treatments required based on the main project objectives*	*Preliminary Estimated costs for this hazard*	*Accountability*	*Reporting required*
Hazard H45 Effectively addressing Hazard sH19 and 21	Below Whalers Pt Lookout	Rockfalls in HW basalt Ext Small (<1.0 m^3)	Users of path below	**HIGH**		Closure of path	Maintain closure of path until remedial works undertaken Maintain warning and hazard signage at entry points to this section Regularly inspected and reviewed on quarterly basis	Significant stabilisation required at Hazard H45 to allow ongoing access on walking path below. Remedial works may include some initial scaling of loose rocks. Re-profiling may also be needed BUT dependent on GSC position on amenity at the Lookout Ideally Soil nailing and mesh required to ensure stability- note potential issue with visual amenity. However cost considerations may mean use of rockfall netting instead. Re-locate lookout fence back to original position as in pre 1985 aerial photos	$75K – $85 K	Top level of management	Reported quarterly
H45	Whalers point	Rockfall in HW and XW basalt Possibly slide	Observers at lookout and lookout/fence	**LOW but only with current barrier**	**SIGNIFICANT**	Open but only acceptable behind barrier	Reposition fence and provide vegetated buffer to cliff edge Maintain closure of area until remedial works undertaken Regularly inspected and reviewed on quarterly basis	Works as above	See costs above	Top level of management	Reported quarterly

Table 15(cont.) Summary of key hazards, risks, management, proposed risk treatments and preliminary cost estimates

Hazard Id	*Location*	*Type*	*Key elements at risk*	*Estimated Equivalent DELWP risk to Life*	*Estimated Equivalent DELWP risk to Infrastructure*	*Existing Management*	*Possible Management Required*	*Possible risk treatments required*	*Preliminary Estimated costs for this hazard*	*Accountability*	*Reporting required*
H47 Effectively addressing Hazard H55a	Below Whalers Point	Rockfall in HW and XW basalt	Users of the path	**HIGH**		Closure of path	Maintain closure of path until remedial works undertaken Maintain warning and hazard signage at entry points to this section Regularly inspected and reviewed on quarterly basis	Significant stabilisation required at Hazard H47 to allow ongoing access on walking path below. Remedial works may include some initial scaling of loose rocks. Re-profiling may also be needed BUT dependent on GSC position on amenity at the Lookout Soil nailing and mesh required to ensure stability due to greater weathering of rock here - note potential issue with visual amenity Re-locate lookout fence back to original position as in pre 1985 aerial photos	$250 to 265K		
H47	Whalers lookout	Slide in XW and HW basalt (top) Very Small (10.5 m^3)	Observers at lookout and lookout/fence	**LOW but only with current barrier**	**SIGNIFICANT**	Open but only acceptable behind barrier	Reposition fence and provide vegetated buffer to cliff edge Maintain closure of area until remedial works undertaken Regularly inspected and reviewed on quarterly basis	Works as above	(see costs above	Senior management	Reported quarterly

Table 15(cont.) Summary of key hazards, risks, management, proposed risk treatments and preliminary cost estimates

Hazard Id	*Location*	*Type*	*Key elements at risk*	*Estimated Equivalent DELWP risk to Life*	*Estimated Equivalent DELWP risk to Infrastructure*	*Existing Management*	*Possible Management Required*	*Possible risk treatments required*	*Preliminary Estimated costs for this hazard*	*Accountability*	*Reporting required*
H48	Behind Whalers Crt	Slide in soils and XW basalt Small (80m^3)	Walkers along cliff edge and reserve	**LOW but only with current barrier**	**SIGNIFICANT**	Open but only acceptable behind barrier	Maintain closure of area until remedial works undertaken Regularly inspected and reviewed on quarterly basis	Stabilisation of headscarp at Hazard H48 required to ensure safe passage along GSWW May include battering back headscarp, removing stormwater pipe and ensuring no intermittent flows and then constructing a retaining structure Provide erosion control below the retaining wall as area is still obviously receiving flows. Work in with drainage study recommended to assess hazards H4 and H5. Further works may need to be implemented depending on outcomes of study Relocate GSWW away from the cliff edge. Delineate the walking path with bollards and/or guideposts and maintain a (minimum distance from cliff edge	$12 -$15K	Senior management	Reported quarterly
H49	Behind Whalers Crt	Slide in soils and XW basalt Small (60 m^3)	Walkers along cliff edge and reserve	**LOW but only with current barrier**	**SIGNIFICANT**	Open but only acceptable behind barrier	Maintain closure of area until remedial works undertaken Regularly inspected and reviewed on quarterly basis	Stabilisation of headscarp at Hazard H49 required to allow passage along the GSWW May include battering back headscarp, removing stormwater pipe and ensuring no intermittent flows and then constructing a retaining structure Provide erosion control below the retaining wall as area is still obviously receiving flows. Work in with drainage study recommended to assess hazards H4 and H5. Further works may need to be implemented depending on outcomes of study Relocate GSWW away from the cliff edge. Delineate the walking path with bollards and/or guideposts and maintain a (minimum distance from cliff edge	$12-15K	Senior management	Reported quarterly

Table 15(cont.) Summary of key hazards, risks, management, proposed risk treatments and preliminary cost

Hazard Id	*Location*	*Type*	*Key elements at risk*	*Estimated Equivalent DELWP risk to Life*	*Estimated Equivalent DELWP risk to Infrastructure*	*Existing Management*	*Possible Management Required*	*Possible risk treatments required*	*Preliminary Estimated costs for this hazard*	*Accountability*	*Reporting required*
H52	Whalers Point	Isolated rockfall from PCL	Users of the path	**HIGH**		Closure of path	Maintain closure of path until remedial works undertaken Maintain warning and hazard signage at entry points to this section Regularly inspected and reviewed on quarterly basis	Stabilisation of Hazard H52 required to allow ongoing access to walking path adjacent to PCL cliff face Works may include scaling individual rocks and providing rockfall netting in problem areas to prevent rocks reaching path.	$12K- $17K	Top level of management	Reported quarterly
H53	Whalers Point	Vertical Collapse in PCL	Users of the path	**MEDIUM TO SIGNIFICANT**		Closure of path	Maintain closure of the path until remedial treatment plan has been developed and implemented Monitored and re-evaluated on 6 monthly basis	Regular monitoring of the Hazard H53 is required as a minimum to allow use of path adjacent to PCL cliff face Install crack meters across the main vertical tension crack and assess movements Depending on results this hazard may either need to be scale off and rockfall netting or alternatively stabilised with a number of rock bolts and mesh/netting	$15K -25K?	Senior management	Reporting 6 monthly
H54	Whalers Point	Rockfall in flaggy limestone	Users of the path	**HIGH**		Closure of path	Maintain closure of path until remedial works undertaken Maintain warning and hazard signage at entry points to this section Regularly inspected and reviewed on quarterly basis	Stabilisation of Hazard H54 is required to allow ongoing access of path below Works should include scaling of unstable rock and re-profiling Use of rockfall netting over this section also recommended	$15K- 17K	Top level of management	Reported quarterly

Table 15(cont.) Summary of key hazards, risks, management, proposed risk treatments and preliminary cost

Hazard Id	*Location*	*Type*	*Key elements at risk*	*Estimated Equivalent DELWP risk to Life*	*Estimated Equivalent DELWP risk to Infrastructure*	*Existing Management*	*Possible Management Required*	*Possible risk treatments required*	*Preliminary Estimated costs for this hazard*	*Accountability*	*Reporting required*
H55	Whalers Point	Complex slide in soil rock and clay	Users of the path	**MEDIUM**		Closure of path	Monitored and re-evaluated on 6 monthly basis This location not required to be closed	No immediate remedial works required at this location	NA	Senior management	Reporting 6 monthly
H57	South of Nuns Beach carpark	Slide in soil/ XW tuff/basalt	Occupant of vehicle on road	**MEDIUM**		Road open	Monitored and re-evaluated on 6 monthly basis This location not required to be closed	No immediate remedial works required at this location	NA	Senior management	Reporting 6 monthly
H58	South of Nuns Beach carpark	Slide in soil/ XW tuff/basalt	Occupant of vehicle on road	**MEDIUM**		Road open	Monitored and re-evaluated on 6 monthly basis This location not required to be closed	No immediate remedial works required at this location	NA	Senior management	Reporting 6 monthly
H68	Lee Breakwater Road	Fall of bluestone blocks	Pedestrians on path	**MEDIUM TO SIGNIFICANT**	**MEDIUM**	Path open	Path can possibly stay open in the short term (DELWP/GSC decision) BUT requires immediate weekly inspections / monitoring and closure if any observations of rocks and bluestone blocks falling outside of fencing Also inspect after heavy rainfall events Reporting on quarterly basis	Risks seen as barely tolerable (GSC and DELWP to confirm) Remedial action recommended for this general Hazard H68 to ensure safe passage by pedestrians in this sector Action could either take the form of specific stabilisation measures or removal of elements at risk from hazard Stabilisation works might include rockfall netting or construction of an engineered rockfall fence/barrier Alternative is to relocate path to the other side of the road and avoid interaction between hazard and elements at risk.	NA	Senior management	Reporting 6 monthly

Table 15(cont.) Summary of key hazards, risks, management, proposed risk treatments and preliminary cost

Hazard Id	*Location*	*Type*	*Key elements at risk*	*Estimated Equivalent DELWP risk to Life*	*Estimated Equivalent DELWP risk to Infrastructure*	*Existing Management*	*Possible Management Required*	*Possible risk treatments required*	*Preliminary Estimated costs for this hazard*	*Accountability*	*Reporting required*
H69	Lee Breakwater Road	Fall of bluestone blocks	Pedestrians on path	**MEDIUM TO SIGNIFICANT**	**MEDIUM**	Path open	Path can possibly stay open in the short term (DELWP/GSC decision) BUT requires immediate weekly inspections / monitoring and closure if any observations of rocks and bluestone blocks falling outside of fencing Also inspect after heavy rainfall events Reporting on quarterly basis	Risks seen as barely tolerable (GSC and DELWP to confirm) Remedial action recommended for this general Hazard H68 to ensure safe passage by pedestrians in this sector Action could either take the form of specific stabilisation measures or removal of elements at risk from hazard Stabilisation works might include rockfall netting or construction of an engineered rockfall fence/barrier Alternative is to relocate path to the other side of the road and avoid interaction between hazard and elements at risk.	Dependent on option chosen but most likely path relocation See GSC for costs??	Senior management	Reporting 6 monthly
H70	Lee Breakwater Road	Fall of bluestone blocks	Pedestrians on path	**MEDIUM TO SIGNIFICANT**	**MEDIUM**	Path open	Risks seen as barely tolerable (GSC and DELWP to confirm) Path can possibly stay open in the short term (DELWP/ GSC decision) BUT requires immediate weekly inspections / monitoring and closure if any observations of rocks and bluestone blocks falling outside of fencing Also inspect after heavy rainfall events Reporting on quarterly basis	Remedial action recommended for this general hazard H68 to ensure safe passage by pedestrians in this sector Action could either take the form of specific stabilisation measures or removal of elements at risk from hazard Stabilisation works might include rockfall netting or construction of an engineered rockfall fence/barrier Alternative is to relocate path to the other side of the road and avoid interaction between hazard and elements at risk.	Dependent on option chosen but most likely path relocation See GSC for costs??	Senior management	Reporting 6 monthly

Table 15(cont.) Summary of key hazards, risks, management, proposed risk treatments and preliminary cost

10. Review of Existing Management Actions

10.1 Comments on past management actions

A review of management practices in the initial study area was undertaken by ASMG in 2014 at the request of GSC. Details of the review are contained in the following report

> *"Portland Cliffs Signage and Barrier Audit- Short term recommendations Report No 734b/01/14. Date 17th April 2014. Prepared for Glenelg Shire Council by A.S.Miner Geotechnical*".

This review confirmed that all management actions taken in 2013 relating to restriction of public access remained in place in 2014 .In particular these access restrictions related to

- Ongoing restriction of access between Nuns Beach to Anderson Point through the use of warning signs and barriers either side of Whalers Point
- Ongoing restriction of access to outer fence at Whalers Point lookout through use of mesh barriers
- Ongoing restriction along the GSWW to cliff edge behind Whalers Court

NOTE: Previous restrictions to the area adjacent to now remediated Hazard H40 (Nuns Beach Slide) have been replaced with a new gabion rock fall interception barrier/structure and a series of timber bollards placed in front to create a further buffer area.

A series of short term recommendations for upgrading of both signs and barriers were recommended in the 2014 ASMG report. It is understood by ASMG based on discussion with GSC that all recommendations were subsequently carried out.

Subsequent review during the current inspection in May 2018 noted that some of the barriers on the beach had been tampered with by the public to allow ongoing access to the walking path below the cliffs between Clifton Beach and Nuns Beach.

As such it is clear that whilst signage and barriers have been installed as per previous recommendations their effectiveness is being nullified by the public who choose to either ignore the warnings and /or actively remove barriers to gain access to restricted areas.

10.2 Recommendations for future management actions

Following the latest inspections and re-assessment of risks following ongoing management actions are recommended:

- Maintain all current exclusion zoning, warning signage and restrictions to public access until remedial works and treatments have been confirmed and implemented.

- Undertake regular inspections (every week and following heavy or prolonged rainfall) of the slopes both above and adjacent to the main access stairs to Clifton Beach from Anderson Point and the access stairs to Nuns Beach.
- Undertake regular inspections (every week and following heavy or prolonged rainfall) of the cliff edge beyond the fence and exclusion zones at Whalers Point lookout. Extreme care must be taken if and when making observations on the outside of the fence.
- Undertake regular inspections (every week and following heavy or prolonged rainfall) of the cliff edge recessions on the public open space reserve behind Whalers Court. Observations of drainage patterns and surface flows are particularly important in assessing the nature and cause of these hazards.
- Undertake regular inspections of the cliffs above the pedestrian path at southern section of Lee Breakwater Road

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11. Other Comments and Recommendations

Based on the information reviewed and additional understanding gained from this study, the following further comments are made:

The initial study area was observed to still have a level of landslide activity. This was mainly in the form of rockfalls in and around Whalers Point. In addition a surficial slide is active immediately adjacent to the Anderson Point stairs and a smaller slide is still evident but not as active near the Nuns Beach access stairs

Activity is continuing in response to frequent significant rinafall events and some seasonal elevation of regional groundwater but nowhere near the levels observed in 1974 (Hanlon Parade landslide), 2007 (Wade Street landslide) and/or 2013 extensive Portland cliff failures).

Some of the sites of other smaller landslides that occurred in 2013 (whilst not showing significant activity between 2013 and 2018) have been over-steepened and in themselves will become more susceptible to future failures under similarly adverse conditions.

A re-assessment of risks using refined estimates of likelihood based on further assessment of preparatory and triggering factors indicates ongoing management actions aimed at isolating the public from potential hazards are still considered valid

Whilst final adoption of risk mitigations and treatments lies with the responsible authority (in this case DELWP and GSC), a number of treatments and management actions have been proposed for consideration to reduce risks levels at significant hazard sites.

As such the following recommendations are proposed as a way forward for the site. It is recommended, subject to resources and funding being made available, that:

- Review of the proposed risk treatments and mitigation works provided for consideration is undertaken for each site listed in Table 15 and undertake a finalisation of options based on organisational risk appetite and site objectives.
- As a minimum, an ongoing monitoring of regional rainfall patterns should be immediately commenced with particular emphasis on the longer term cumulative totals which are postulated as a good proxy for overall groundwater levels.
- Develop a management plan for stakeholders that links threshold values with management actions with clear operational and procedural protocols
- An inventory of failures must be developed and maintained with all new landslide hazards documented with the same level of information as detailed in this report.
- It is recommended that all paths and open space closures remain in place until remedial works and revised management actions have been undertaken.
- Consider a public information and awareness program aimed at increasing understanding of the dynamic nature of the coastal setting and informing people of the potential hazards

12. Information about this report

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Statement of Limitation - Landslide Risk Assessment.

The process of risk assessment involves estimation of likelihood, consequence and risks based on available information for the study site. By its very nature much of the data such as rockfall or landslide inventory for this site and the immediate surrounds will be incomplete. Judgement is required to estimate the nature and size of potential hazards and their impact of a variety of elements at risk. As such there is no right answer (unique probability) that can be found by risk analysis. As these judgements are based on knowledge, experience and understanding of the assessor it is not unusual for different assessors to make different judgements about the level of risk

In landslide risk assessment the greatest uncertainty is associated with assessing landslide likelihood. A temporal understanding of the potential hazards is one of the most difficulty parts of the process and usually requires the combination of degrees of belief in combination with available observations and even useful anecdotal information.

The thought process used in establishing likelihoods, consequences and determining spatial and temporal factors has been documented to allow a more transparent process. Many of these thoughts and judgements are subjective and based on available but still incomplete data. Whilst the structure of the risk assessment process is well defined this should not be mistaken for precision and the limitations of the inputs are duly acknowledged.

Generally the levels of likelihoods and risks should be thought of a being within a range of typically +/- half an order of magnitude. Whilst the basis for the judgements contained in this report are well documented and the levels of risk considered to be good representations of reality, the accuracy of the process should not be overestimated and should always be used in an appropriate manner in combination with risk mitigation and risk treatment options.

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Figures

Appendix A

Previous Information relating to Site Conditions

(Extract from ASMG 2013)

Appendix B

Previous Information relating to Site Conditions

(Extract from ASMG 2013)

Appendix C

Historical Aerial Photography Assessment

Appendix D

Field Observations

Appendix E

Landslide Terminology and Definitions

Appendix F

Hazard Identification and Reporting

Appendix G

Risk Assessment Methodology

Appendix H

Hazard Comparisons

September 2013 to May 2018

Appendix I

Rainfall Analysis

Appendix J

Risk Assessment Reporting